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Subject: Deliverable Number 0011, ICODES Extension Technical Report

Reference: Strategic Mobility 21 Contract N00014-06-C-0060

Dear Paul,

In accordance with the requirements of referenced contract, we are pleased to submit this ICODES Extension Technical Report for your review.

Your comments on this document are welcomed.

Regards,

A handwritten signature in cursive script, appearing to read "Lawrence G. Mallon".

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Director, Naval Research Lab (Hardcopy via U.S. Mail)  
Defense Technical Information Center  
Stan Wheatley



## Strategic Mobility 21

### ICODES Extension Technical Plan

### Contractor Report 0011

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***Strategic Mobility 21 – CLIN 0011***

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# Table of Contents

|   |    |
|---|----|
| Table of Contents .....   | ii |
| List of Figures .....   | iv |
| List of Tables .....  | v  |
| Abstract .....  | vi |
| 1. SM21 Project Context .....                                     | 1  |
| 1.1 The Military Perspective .....                                | 1  |
| 1.2 The Commercial Perspective .....                              | 2  |
| 1.3 The Local Government Perspective .....                        | 2  |
| 1.4 The Public Perspective .....                                  | 2  |
| 2. Technical Approach .....                                       | 3  |
| 2.1 Military Requirements and Technology Developments .....       | 3  |
| 2.2 Information-Centric Software .....                            | 5  |
| 2.3 An Information-Centric Suite of Software Tools .....          | 6  |
| 3. Capabilities of the ICODES Toolset .....                       | 9  |
| 3.1 Operational and Technical Objectives .....                    | 10 |
| 3.2 Interoperability with External Systems .....                  | 11 |
| 3.3 Agent Capabilities .....                                      | 12 |
| 3.4 Thick-Client User-Interface .....                             | 14 |
| 3.5 Thin-Client User-Interface .....                              | 16 |
| 3.6 The ICODES Viewer .....                                       | 17 |
| 3.7 The ICODES Observer .....                                     | 18 |
| 3.8 The JINNI Module .....  | 19 |
| 3.9 Reference Libraries .....                                     | 20 |
| 3.10 Data Import Requirements and Options .....                   | 26 |
| 3.11 Hardware Requirements .....                                  | 27 |
| 4. Capabilities of the TRANSWAY Toolset .....                     | 28 |
| 4.1 Extensible Functional Capabilities .....                      | 28 |
| 4.2 Using the TRANSWAY Toolset .....                              | 29 |
| 4.3 Operational Interrelationships .....                          | 29 |
| 4.4 The TRANSWAY Agents .....                                     | 31 |
| 5. The ICODES-TRANSWAY Toolsets in an Experimental Exercise ..... | 35 |
| 5.1 The Exercise Scenario .....                                   | 35 |

|  |    |
|--|----|
| 5.2 Applying the Capabilities of the ICODES-TRANSWAY Toolset ..... | 36 |
| Appendix A: ICODES Data Dictionary .....                           | 39 |
| Appendix B: Typical TRANSWAY Planning Scenario .....               | 46 |
| Appendix C: TRANSWAY Data Dictionary .....                         | 62 |
| Appendix D: References .....                                       | 68 |
| Appendix E: Acronyms .....   | 69 |

## List of Figures

|   |    |
|---|----|
| Figure 1. Ship load-planning with the ICODES toolset .....            | 7  |
| Figure 2. Delivery and route planning with the TRANSWAY toolset ..... | 8  |
| Figure 3. Load-planning as a complex problem .....                    | 9  |
| Figure 4. Military deployment objectives .....                        | 9  |
| Figure 5. ICODES thick-client user-interface .....                    | 14 |
| Figure 6. The ICODES Observer user-interface .....                    | 18 |
| Figure 7. Typical TRANSWAY operational sequences .....                | 29 |
| Figure 8. Trip generation flow diagram .....                          | 33 |

## List of Tables

|          |  |    |
|----------|--|----|
| Table 1. | Reference Library <i>49 CFR</i> Data Dictionary .....        | 21 |
| Table 2. | Reference Library <i>DCMNSN</i> Data Dictionary .....        | 22 |
| Table 3. | Reference Library <i>DoDIC</i> Data Dictionary .....         | 22 |
| Table 4. | Reference Library <i>ECF</i> Data Dictionary .....           | 22 |
| Table 5. | Reference Library <i>IMDG</i> Data Dictionary .....          | 23 |
| Table 6. | Reference Library <i>MECF</i> Data Dictionary .....          | 24 |
| Table 7. | Reference Library <i>Tech</i> Data Dictionary .....          | 24 |
| Table 8. | Reference Library <i>Symbol Lookup</i> Data Dictionary ..... | 25 |

## **Abstract**

This report describes the capabilities of the ICODES (Integrated Computerized Deployment System) and TRANSWAY suite of tools in the logistical domain. It addresses in particular their suitability for supporting an end-to-end military deployment exercise that is scheduled to occur within the Southern California public transportation corridor sometime in the first half of 2007. In support of this planned exercise the ontology-based intelligent agents of the ICODES-TRANSWAY adaptive toolset will be able to assist operators in the staging of cargo in marshalling yards, the load-planning of cargo onto multiple conveyance types (i.e., trucks, railcars, and ships), and the planning and re-planning of delivery plans along alternative surface routes and air channels within a geo-spatial reference frame.

# **ICODES Extension Technical Plan**

## **Adaptive Software for Simulation Demonstration Support**

### **1. The SM21 Project Context**

The broad objectives of the multi-year SM21 project are to gain significant efficiencies in the distribution components of the end-to-end commercial and military supply chain processes. More specifically, the SM21 project is focused on the expeditious transportation of goods through existing public and commercial traffic corridors in the Continental United States (CONUS). Project end-objectives include not only recommendations and guidelines that can be followed by military, commercial, and government planners, but also simulations, system demonstrations, real world exercises, and Community of Interest (COI) conferences. In addition, it is expected that the SM21 project will generate useful *leave-behind* components in the form of computer software and a reproducible, regional, goods movement control center.

The principal players that are involved in the transportation of goods in CONUS include: commercial vendors and transporters; local government authorities; the military; and, the public. These players share certain common interests in addition to their individual requirements, responsibilities, and expectations. All of them desire to be able to travel from an origin to a destination without disruption, quickly and safely, regardless of any temporary circumstances that may impact traffic conditions or the availability of a particular transportation mode or traffic route.

#### **1.1 The Military Perspective**

The military are mostly concerned with the deployment and sustainment of forces. During deployment, forces of up to division size (at least 10,000 troops) are required to be transported with their equipment from the garrison to a Port of Embarkation (POE) for mostly surface shipment to an overseas theater. The typical modes of transportation through a given CONUS traffic corridor to a particular POE are truck convoys and rail.

As a rule a deployment movement is carefully planned in advance and typically executed under some time constraints. While the minimum disruption of commercial and public traffic is certainly a concern, the overriding objective of the military planners and operators is to move the soldiers and their equipment within clearly defined time windows, while maintaining in transit visibility, security, and control throughout the movement. Since even the most carefully laid plans are subject to disruption due to unforeseen events, the military have a critical need for continuous situation awareness and rapid re-planning capabilities.

The military planners require access to information relating to alternative routes, conveyance characteristics and availability, expected and actual traffic conditions, staging and marshalling yard facilities, expected and actual weather conditions, and intelligence analyses that may be classified. These data requirements suggest the attendant need for information systems that are seamlessly interoperable and include adaptive decision-assistance tools that are capable of automatically adjusting to the range of variations that tend to occur in real world situations. Foremost among these decision aids are software tools for the selection of the most suitable conveyances, the load-planning of various kinds of conveyances (i.e., trucks, railcars, barges, ships, and aircraft), the laying out of staging areas and marshalling yards, the planning and re-planning of optimum routes, and the tracking and monitoring of goods as they move from origin to destination.

The processes involved in military sustainment planning and execution are quite different from the deployment processes summarized above. Once forces have been deployed to a theater, the sustainment of these forces with provisions, clothing, fuel, spare parts, and other supplies<sup>1</sup>, is mostly outsourced to commercial companies. Therefore, the movement of sustainment supplies forms a regular part of commercial traffic and does not normally impose surge conditions on public transportation corridors. Since it is not possible to determine with any degree of accuracy the proportion of commercial traffic that is at any one time involved in military sustainment operations, the SM21 project is unlikely to be able to include sustainment considerations in any of its real world demonstration exercises.

## **1.2 The Commercial Perspective**

Shipment speed, cost, security, and minimum labor requirements, are the primary commercial concerns. Traffic congestion, as well as loading, unloading, and inspection delays at railheads, ports and border crossings are significant cost factors. Due to current congestion levels CONUS, ports such as Los Angeles and Long Beach would have difficulty accommodating a major military deployment if, for example, the San Diego port facilities became unavailable due to terrorist activity or a labor strike.

## **1.3 The Local Government Perspective**

Among local government agencies: law enforcement is concerned with the control of traffic flow and general security; port authorities are concerned with the efficient operation and security of the port facilities; and, local organizations such as the Chamber of Commerce are concerned with the economic health of their commercial members. In addition, certain State departments (e.g., Department of Transportation) exercise control over some aspects of State highways such as the maximum loaded size and weight of conveyances (e.g., roadside weigh-stations).

An increasing number of the major traffic arteries in large cities such as Los Angeles are monitored with video cameras and sensing devices to measure traffic flow for both future planning and near real time traffic management purposes. The data collected by these automated monitoring devices potentially constitutes a valuable source of information for the SM21 project. While this information can be easily incorporated in simulation models, it is unlikely that permission can be obtained for live feeds during demonstration exercises.

Finally, emergency services such as the local fire department and ambulance services must be able to reach their target destination with utmost speed and reliability. Some of these units are able to exercise control over traffic lights to facilitate their rapid movement through intersections and similar traffic bottlenecks. In many cases, these services are able to communicate both by voice and electronically with traffic command centers to obtain information on current traffic patterns and advice on alternative routes.

## **1.4 The Public Perspective**

The private citizen driver does not wish to be inconvenienced. In large urban areas such as greater Los Angeles, commuting times to places of work are seldom less than one hour and often more than two hours during peak traffic periods. Additional delays caused by large military convoys are unlikely to be acceptable to the public, requiring the military to schedule their deployment movements during the night hours (i.e., midnight to 5 am). This may be a critical planning limitation in the case of large deployments that cannot be completed in less than five hours.

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<sup>1</sup> An exception is ammunition, which is shipped from a very small and select number of POEs (i.e., Sunny Point (NC) and Concord (CA)) and typically involves military personnel to a much greater extent than other types of sustainment supplies.

## 2. Technical Approach

As part of its objectives SM21 proposes the development of an integrated transportation planning, operational monitoring, and coordination system to enable the effective integration of military deployment operations with normal commercial goods movement in urban traffic corridors. The proposed system will include: (1) a robust database repository that can be distributed over multiple network nodes, populated with software objects; (2) expert agents that can reason about these objects and their relationships, thereby automating simple but time consuming analytical functions now performed by human operators; and, (3) interfaces to existing data sources that provide important contributions to a common operational transportation picture. This system will build on intelligent agent technology and software objects already created for and used by the military.

### 2.1 Military Requirements and Technology Developments

Within the US Department of Defense (DoD) USTRANSCOM has *joint* logistic responsibilities for the deployment and sustainment of forces. In recent years USTRANSCOM recognized the need for advanced information technology to efficiently execute its responsibilities as DoD's Distribution Process Owner (DPO). Since some of the software tools that were developed in support of this initiative are proposed to become core components of the SM21 system, it is appropriate to briefly discuss the military requirements that led to the development of these software tools.

The military deployment and sustainment requirements are generated at the operational level and are dynamic. They are composed of shifting priorities responding to changes in commander's intent and changes in the operational situation. However, while commander's intent and future plans normally drive these requirements, it is also possible for the reverse to occur. Unit movement (i.e., deployment) and sustainment flow planning and execution monitoring are largely planned and executed at the strategic level, responding to ship and aircraft availability and other gross transportation factors only indirectly related to the changing operational priorities in the theater. Strategic flow planning and execution processes are focused on logistic efficiency and tonnage, while satisfying operational requirements is focused on logistic effectiveness (i.e., providing the right thing in the right quantity at the right place at the right time to the right units). The following were identified by military logistic planners and operators as the kinds of tools required:

- Intelligent decision support tools that directly translate force and mission plans (i.e., courses of action (COA)) into statements of logistic requirements with associated inventory based opportunity costs and risks.
- Intelligent decision-support tools to assist in generating and re-generating sustainment requirements based on commander's intent and proposed COA and that support rapid generation and assessment of alternative COAs when unexpected changes occur.
- Intelligent decision-support tools that assist in the load-planning of air and surface (ships, truck convoys and rail) conveyances.
- Intelligent decision-support tools that can assist in the space and time management of staging areas at ports and in supply centers.
- Intelligent decision-support tools that detect changing sustainment priorities and automatically generate options that integrate transport assets, inventory availability, and on-going operations.

- Intelligent decision-support tools that are capable of integrating theater infrastructure capacities and characteristics (as well as changes to these) into sustainment and distribution plans, and projections.
- Intelligent decision-support tools that ensure continuous visibility of both the dynamic sustainment requirements and the strategic sustainment plans generated in response to these requirements.

Much of the time of military planning and operational staff is currently spent on determining the location and status of shipments that have failed to arrive at their destinations within the expected time windows. Therefore, staff must be able to lodge a query about a particular shipment or group of shipments and pursue this query to reasonable depth utilizing a wide variety of search keys, such as:

- Where is this shipment right now? Rapid identification of the shipment is desired, based on several alternative search keys.
- Where was the shipment last reported to have been seen or identified?
- What has been the event-by-event or node-to-node history of the shipment from the time it was first requested?
- What lift assets are available to expedite the movement of this shipment from where it is now to its intended destination? What are the risks? What are the actual costs? What are the opportunity costs?
- Where are additional supplies available as a replacement for a temporarily or permanently lost high priority shipment?

The operator should be able to click on any displayed track and obtain information relating to that track, such as:

- What does the track represent in terms of shipment identification, shipment type, and current transport mode (i.e., conveyance)?
- What is the last reported location of the track and what is the date and time of that location report?
- What is the next destination (i.e., node) of the track and what is/was the planned arrival date and time?

Similarly, it should be possible to seamlessly move from the track level data to the more detailed shipment data, such as:

- What is the priority of the shipment?
- What is the content of the shipment in terms of quantity and Class of supplies?
- What was the origin of the shipment and the start date/time of the movement?
- What is the final destination of the shipment and who requested it? When was it requested? What was the requested delivery date/time? What was the delivery date/time according to the original movement plan? When is it most likely to be actually delivered?
- What is the node-to-node movement plan for this shipment? Where is it now in respect to this plan and what is the remaining portion of the plan that must still be executed?

Both the formulation and execution of movement plans will be impacted by external factors such as weather conditions, traffic conditions, availability of commercial transportation, terrain, threat levels, and so on. In this respect an adaptive toolset should be able to accept several on-line data feeds and combine the imported data with sufficient context to allow software agents to automatically reason about the implications of the external factors. Candidate data feeds include:

- Weather forecasts on a regional and local level.
- Indigenous transportation systems (e.g., major roads, railways, ferries, commercial airline routes) in regions and local areas that may be used for shipments.
- Infrastructure objects such as military bases, traffic arteries, fuel stations, depots and warehouses, railway stations, ferry stations, airports, ocean ports, and so on.

USTRANSCOM recognized that as the scale of the available adaptive toolset progressively encompassed a more significant portion of the military deployment, sustainment, and distribution responsibilities, the intelligent components of the software would have access to an increasingly larger set of historical data. It was reasoned that this would in time provide a fertile ground for agent-based software with more sophisticated analysis and case-based reasoning capabilities. Such agents, operating in a collaborative manner, should be able to analyze past shipments on a continuous basis and be able to respond to the following kinds of questions:

- What quantity of any particular Class of supplies has been delivered over a given time period, what shortage are likely to arise, and when?
- What were the principal choke points where shipments have been delayed during a given time period? Where are choke points likely to occur in the future based on current deployment projections?
- What has been the average time that certain kinds of shipments have taken over a given time period and how do these times relate to planned future movements?
- What have been the relative densities of air, surface and rail movements over a given time period and how do these densities relate to deployment and distribution performance?

It has been apparent to USTRANSCOM and other military organizations<sup>2</sup> for some time that these kinds of adaptive planning and execution requirements cannot be met by legacy software systems that process data without representing the *context* in which the data are expected to be used.

## **2.2 Information-Centric Software**

Advancements in computer software technology over the past decade have elevated computer-based data-processing to intelligent information management. In such *information-centric* decision-support systems software modules (referred to as agents) are able to automatically reason within the *context* of an internal information model (rather than data representation) to collaboratively assist each other and human operators in the near real-time monitoring of current events, planning for future events, and the analysis of alternative courses of action (Pohl 2001).

The key difference between a data-processing and an information-centric environment is the ability to embed in the information-centric software some understanding of the information being processed. The term *information-centric* refers to the representation of information in the computer, not to the way it is actually stored in a digital machine. This notion of *understanding* can be achieved in software through

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<sup>2</sup> See: 'Adaptive Planning Roadmap', Office of the Secretary of Defense, 3 January 2005 (Draft).

the representational medium of an ontological framework of objects with characteristics and interrelationships (i.e., an internal information model). How these objects, characteristics and relationships are actually stored at the lowest level of bits in the computer is immaterial to the ability of the computer to undertake reasoning tasks. The conversion of these bits into data and the transformation of data into information, knowledge and context takes place at higher levels, and is ultimately made possible by the skillful construction of a network of richly described objects and their relationships that represent those physical and conceptual aspects of the real world that the computer is required to reason about.

An information-centric software architecture is by its nature an open architecture that typically consists of components (i.e., service modules) that exist as clients to an integrated collection of services. Incorporating such services, an information-serving collaboration facility communicates to its clients in terms of the real world objects and relationships that are represented in the information structure (i.e., the underlying ontology). The software code of each client includes a version of the ontology, serving as the common language that allows clients to communicate information rather than data. The technology is inherently scalable and allows for the creation and interconnection of multiple object serving communication facilities.

### **2.3 An Information-Centric Suite of Software Tools**

Over the past decade the Collaborative Agent Design Research Center (CADRC) at Cal Poly (San Luis Obispo) in conjunction with its commercial arm, CDM Technologies, Inc., has developed a suite of information-centric software tools in support of military deployment and distribution processes. All of these tools feature agents that are capable of reasoning about data in the context provided by an internal ontology representation. Two subsets of these tools, referred to under the names of ICODES and TRANSWAY, are planned to provide a major portion of the capabilities that have been established for the SM21 system.

The ***Integrated Computerized Deployment System (ICODES)*** is a set of logistic software tools for conveyance load-planning that utilizes intelligent software agents in a human-computer collaborative mode. As an example of a new generation of ‘information-centric’ military decision-support systems, ICODES includes expert agents with automatic reasoning and analysis capabilities. This is made possible by an internal virtual representation of the load-planning environment, in terms of conveyance and cargo characteristics and the complex relationships that constitute the context within which load-planning operations are performed. ICODES agents monitor the principal determinants of cargo stowage, including: the placement and segregation requirements for hazardous cargo items; the trim, list, stress, and bending moments of ship structures; the accessibility of stow areas through ramps, cranes, elevators, hatches, and doors; the correct placement of cargo items in respect to fire lanes, no-stow areas, reserved stow areas, and inter-cargo spacing tolerances; and, the accuracy of cargo characteristics (e.g., dimensions, weight, type, and identification codes) relative to standard cargo libraries and associated reference tables (Figure 1).

In addition, ICODES includes the ***JINNI*** module that allows users to create staging areas and marshalling yards, giving ICODES the ability to support load-planning operations in the broader spectrum of tracking cargo through the deployment stages of assembly, staging, load-planning, and the rearrangement of load-plans during transit<sup>3</sup>.

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<sup>3</sup> Often required on amphibious assault ships (USMC) when the Commander receives new mission orders while en route.



Figure 1: Ship load-planning with the ICODES toolset

The **TRANSWAY** suite of tools supports the development of delivery plans along alternative surface and air routes utilizing multi-modal conveyances (i.e., truck convoys, ships, fixed-wing aircraft, and helicopters). Like the ICODES toolset it is also implemented as a set of intelligent collaborative tools supporting operators performing planning and re-planning tasks in a dynamically changing decision-making environment (Figure 2). The internal ontology is divided into logical domains that can be described using the Unified Modeling Language (UML) methodology. Within each domain exist definitions of the various concepts and entities relevant to the representation and analysis of key aspects of that domain.

TRANSWAY includes two kinds of agents with strategic and operational planning and re-planning capabilities, respectively. The strategic planning agents are based on the Tabu genetic search algorithm and the operational planning agents are rule-based and implemented in Java.

Tabu Search is a local search method for exploring a solution space. In the TRANSWAY implementation of the Tabu genetic algorithm the solution space is every possible planning recommendation. Starting from an initial empty plan, new plans are generated and immediately evaluated based on a merit function. The highest rated plan then becomes the new incumbent best solution, followed by a repetition of the same procedure. Once some ending criterion has been reached the algorithm may stop and report the best solution that it has found or, as in the current version of TRANSWAY, reporting may occur on a continuous basis as better and better solutions are found.

The Re-Planning Agent prepares plans for the delivery of cargo to the required destinations and re-plans when necessary. Planning and re-planning sequences proceed in three basic steps, as follows: (1)

extraction of the current problem domain model from the ontology; (2) preparation of a solution plan that does not violate any of the logistical constraints; and, (3) injection of the problem domain model of the solution plan back into the ontology.

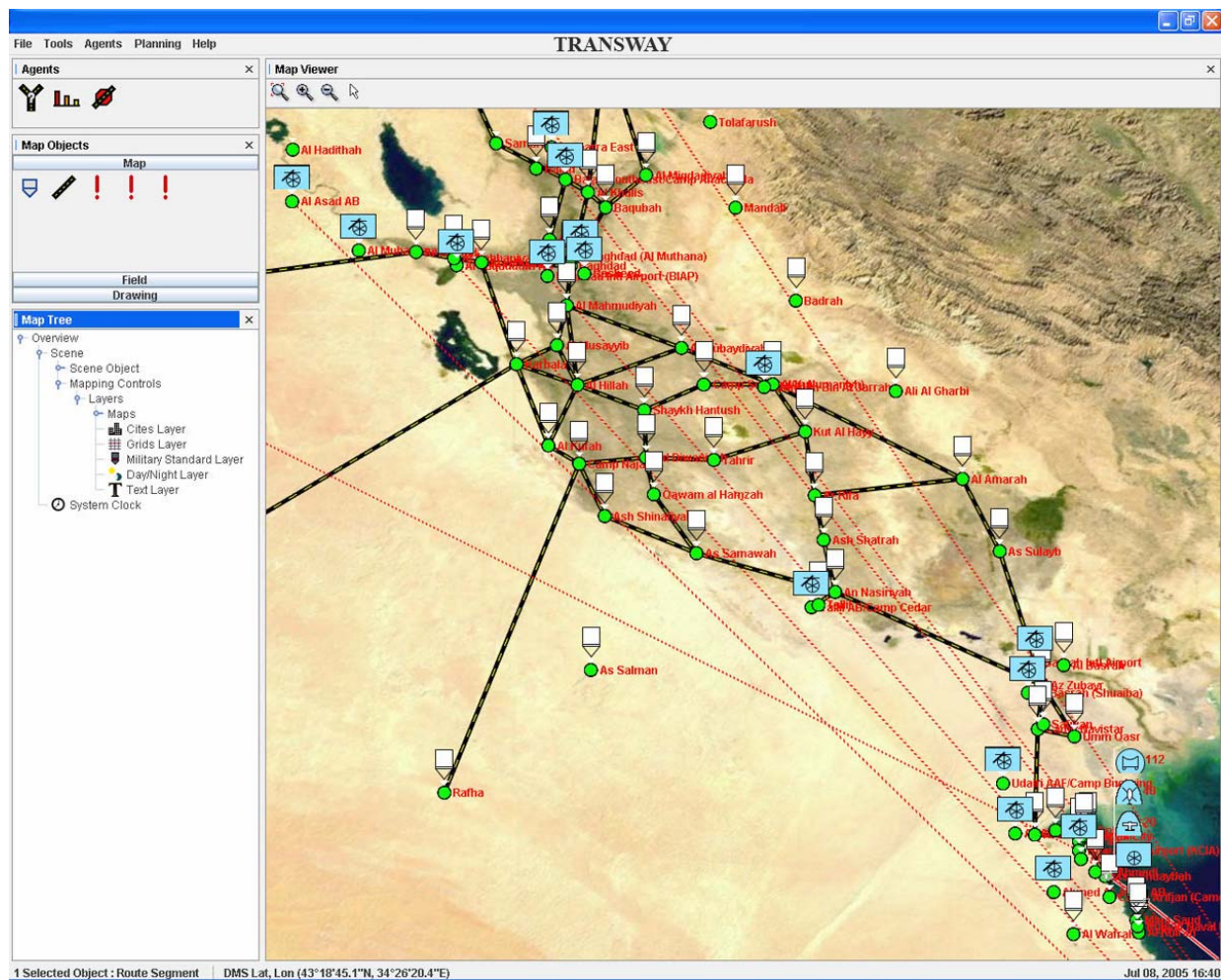


Figure 2: Delivery and route planning with the TRANSWAY toolset

### 3. Capabilities of the ICODES Toolset

The rapid deployment of military assets from CONUS to overseas locations is a complex undertaking. It involves the movement of large numbers of tracked and wheeled vehicles, rotary aircraft, weapon systems, ammunition, power generating and communication facilities, fuel, food supplies, and other equipment and goods, from military bases to the Area of Responsibility (AOR). Several modes of transportation are typically involved. Depending on the location of the military base the assets are preferably moved by road to the nearest railhead, from where they are loaded onto railcars for transportation to the POE.

Alternatively, if rail transportation is not an option, all of the cargo must be shepherded through the public road corridor from the base to the port. At the POE the assets are briefly assembled in staging areas and then loaded onto vessels for shipment. Points of debarkation may vary widely from a commercial shipping port with fairly good facilities to an amphibious landing on a hostile shoreline under fire.

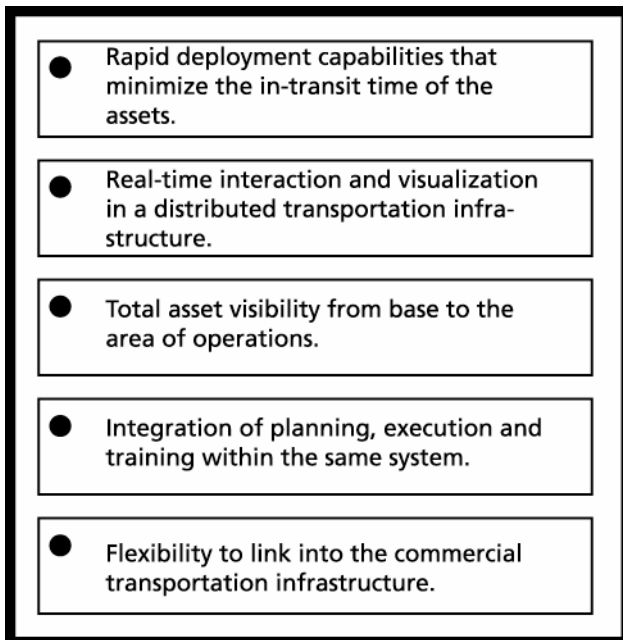


Figure 3: Load-planning as a complex problem



Figure 4: Military deployment objectives

Speed and in-transit visibility are of the essence (Figure 3). The total time required for the loading and unloading of the conveyance is a critical factor and largely determined by the quality of the load-plan. For example, the load-planning of an ocean-going ship has many of the characteristics of a complex problem situation (Figure 4). First, there are continuous information changes. The vessel that arrives at the port may not be the vessel that was expected and that has been planned for. This means that the existing load-plan is no longer applicable and a new plan has to be developed. Similarly, last minute cargo changes or inoperative lifting equipment may require the existing plan to be modified or completely revised.

Second, there are several complex interrelationships. The cargo on any one ship may be destined for several ports of debarkation (POD), requiring careful consideration of loading and unloading sequences. However, these sequences must take into account unloading priorities that may be dictated largely by tactical mission plans. In addition, the placement of individual cargo items on board the ship is subject to hazardous material regulations and practices. These regulations are voluminous, and complex in

themselves. At times they are subject to interpretation, based on past experience and detailed knowledge of maritime risks and practices. Finally, the trim and stability characteristics of the ship must be observed throughout the planning process.

Third, there are many loading and unloading constraints. Some of these constraints are static and others are dynamic in nature. For example, depending on the regional location of the port, external ship ramps may not be operable under certain tide conditions. Local traffic conditions, such as peak hour commuter traffic and rail crossings, may seriously impact the movement of cargo into staging areas or from staging areas to the pier. While these constraints are compounded whenever loading operations occur concurrently, the general complexity of the load-planning problem is exacerbated by the number of parties involved. Each of these parties plays an important role in the success of the operation, but may have quite different objectives. Certainly, the objectives of the commercial stevedore crews that carry out the actual loading tasks are likely to differ markedly from the prevailing military objectives (e.g., rapid loading and unloading operations, safety, unit integrity, load density, documentation accuracy, and security).

### **3.1 Operational and Technical Objectives**

Several general and specific operational and technical objectives were specified by the military users at the beginning of the development process. Foremost, it was the vision of the sponsor that ICODES should present itself to the user as a suite of collaborative and expert tools, rather than a conglomeration of predefined solution templates. Experience had shown that the problems encountered in the real world of conveyance load-planning were driven by dynamically changing factors that were often unpredictable. Accordingly, any predetermined solutions based on preconceived requirements were unlikely to adequately address the nuances of the cargo stowage problem encountered under actual operational conditions.

From an operational viewpoint, ICODES was required to be magnitudes faster than an existing DOS-based ship load-planning application. In summary, it should allow the concurrent planning of four conveyances, provide the user with continuous assistance in the form of alerts and warnings throughout the load-planning process, incorporate an automatic cargo placement capability, link to several external systems but be capable of operating in a stand-alone mode, and offer a friendly and flexible, graphical user-interface that could be customized by the user to suit individual needs.

The general technical objectives included the requirement of an open architecture, the ability to add new and enhance existing user-assistance capabilities over the lifetime of the application, the ability to add future modules to support related functional areas such as inter-modal transportation and port planning (e.g., management of staging areas), and the ability for the user to create cargo lists and conveyances within the application if these were not available within ICODES and could not be imported from existing external systems.

Specifically, the ICODES toolset was required to automatically alert the user of cargo placements within stow areas that are in violation of hazardous material mandates, the trim and stability requirements in the case of a ship conveyance, or a host of cargo stowage rules such as adjacency tolerances, fire lanes, boom clearances, and movement restrictions (e.g., door and hatch dimensions, crane lifting capacities and reach, ramp and elevator constraints, and stow area heights). Such agent-based analysis was to be provided in both a manual stow and an assisted stow capacity. As implemented, the latter of these modes allows the embedded agent community to develop a high quality load-plan through collaboration based on the same expert analysis applied during its manual counterpart.

For example, in the hazardous material domain these specific objectives require ICODES to be able to differentiate among the internationally recognized nine classes of hazardous material, and the sub-groupings or divisions that exist in five of these classes. In addition, interpret and apply the regulations prescribed in the following four principal reference sources:

- The 49 Code of Federal Regulations (49 CFR) that specifies segregation requirements for hazardous cargo shipments in the Continental United States (CONUS).
- The International Maritime Dangerous Goods (IMDG) library that applies to all international shipments of hazardous materials.
- The Department of Defense Identification Code (DoDIC) library that applies specifically to Class 1 hazardous items (i.e., explosives), namely munitions.
- The Dangerous Cargo Manifest National Stock Number (DCMNSN) library that is used primarily by the Marine Corps for identifying and load-planning hazardous cargo items.

Today the ICODES agent-based, decision-support system successfully addresses this entire gamut of requirements. Through ICODES the user is empowered with a decision-support tool that provides both the expert stow planner as well as the novice user with a rich collaborative set of capabilities, providing detailed visibility and intelligent planning and re-planning capabilities in a complex and highly dynamic operational environment.

### **3.2 Interoperability with External Systems**

In 1996, ICODES was selected as the *migration* system for ship load-planning by DoD, and became the *system of record* with the release of Version 2 in 1997. It has been deployed by USTRANSCOM through the Surface Deployment and Distribution Command (SDDC)<sup>4</sup> to the US Army since 1999 and the US Marine Corps since 2002. Other users include the US Navy and the British Army.

ICODES interfaces with the World-Wide Port System (WPS), the Transportation Coordinators' Automated Information for Movement System (TCAIMS-II), the MAGTF Deployment Support System (MDSS-II), the Integrated Booking System (IBS); TRANSWAY (for route planning); and, the Joint Forces Collaborative Toolkit (JFCT) for sea-basing operations.

Throughout load-planning operations ICODES is capable of receiving cargo lists from WPS, MDSS-II, TCAIMS-II, and IBS. However, ICODES currently has two-way connections (i.e., ability to import and export) with only the MDSS-II and TCAIMS-II systems. To facilitate the frequent updating of cargo lists during load-planning operations a *Merge* function identifies new and existing data items and automatically alerts the user to any anomalies, such as cargo items with duplicate TCN numbers. In 2003, ICODES was certified as Level 7 compliant with Defense Information Infrastructure Common Operating Environment (DII-COE) standards. These standards outline rigorous government requirements for software installation, configuration, as well as run-time and interoperability behavior. Development and testing is in progress to support a two-way interface with WPS. This two-way interface is scheduled to be released with the next version of ICODES at the beginning of 2007. Additionally, research is currently underway to support an interface with the Global Air Transportation Execution System (GATES), which is scheduled to replace WPS in 2008.

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<sup>4</sup> Previously known as the Military Traffic Management Command (MTMC) and renamed in 2004, SDDC is a component command of USTRANSCOM responsible for surface movement operations.

### 3.3 Agent Capabilities

The expert agents in ICODES are designed to assist the load-planner in the knowledge domains of hazardous material, trim and stability of ship conveyances, cargo access paths, cargo attribute verification, and the actual placement of cargo in stow areas. The agents continuously communicate with each other as they collaborate in their assistance functions.

When the user is developing a load plan while operating in the manual *User Stow* mode, the agents will alert the user to any violations by turning the surround of the appropriate agent status window red. The user can then click on the status window to display a window with an explanation of the violation. In fact ICODES provides several different types of agent warnings:

- **Yellow** surround of agent status window indicates warning of a situation that could lead to a potential violation
- **Orange** surround of agent status window indicates warning has been acknowledged but still exists
- **Red** surround of agent status window indicates violation indicating the existence of a serious problem
- **Purple** surround of agent status window indicates violation has been acknowledged but still exists

If the user operates in the automated *Assisted Stow* mode the agents will collaborate to place the cargo in such a manner that there are no violations. Cargo items that could not be placed in any stow area without causing a violation are simply not stowed.

Brief summaries of the functional capabilities of each ICODES agent are provided below.

**Stow Agent:** The Stow Agent supports manual and automatic stow-planning operations, as well as a combination of both of these modes. In the case of a ship conveyance, using default settings in the automatic mode (i.e., Assisted Stow) the Stow Agent attempts to place the heaviest cargo items as low as possible on the ship without causing a violation. This results in a low center of gravity for the ship, which is desirable in most cases. The Assisted-Stow mode provides a comprehensive set of settings. This allows the user to define exclusive and inclusive constraints and preferences in respect to both the cargo that is required to be stowed and the stow areas that have been designated as being available. The Stow Agent checks to see that the placement of a cargo item does not overlap another cargo item, a fixture of the conveyance such as a stanchion or fire lane, or if the item is not entirely within a stow area. In Assisted-Stow mode, the user can also set the front/back and side to side spacing requirements of a cargo item. The Stow Agent will abide by these settings and not stow within that imagery boundary around each cargo item.

Other parameters checked by the Stow Agent include the POE and POD to ensure that they match the ports indicated in the voyage documents, and the height of each cargo item to ensure that the latter can reach its final stow position. The Stow Agent automatically adds a safety cushion (specified by the user) to the actual height, to make sure that height plus the cushion does not exceed the maximum allowable height for cargo in that stow area.

While in the *Assisted Stow* mode ICODES will ensure that the automatically generated load-plan has no violations, in manual mode (i.e., *User-Stow*) ICODES will allow the user to stow cargo items that are in violation. However, the Stow Agent will alert the user of the violations and provide an explanation on request.

**Access Agent:** The Access Agent checks all paths to ensure that a cargo item can be stowed in a particular stow area. This includes openings, doors and hatches, differentiating (in the case of a ship conveyance) between cargo that is loaded with cranes through hatches (i.e., Lift-On-Lift-Off or LOLO) and cargo that is driven or pulled into stow areas (i.e., Roll-On-Roll-Off or RORO). Under Assisted Stow conditions, if there is a violation in the stow path of a particular cargo item the Stow Agent will not place this cargo item in that stow area but will attempt to place it in another stow area. In this situation the violation is transmitted directly from the Access Agent to the Stow Agent without notification of the user.

In manual mode (*User Stow*), on the other hand, if a cargo item is placed in a particular stow area for which all of the possible stow paths register an access violation then the Access Agents will inform the user that the cargo item has a violation for every path to the stowed location. In addition, the Stow Agent will identify for the user the shortest stow path and the nature of the violation that is associated with that path.

ICODES allows the user to edit conveyance characteristics in the case of ships, including the usability properties of the cranes and the dimensions of doors, openings and hatches. Since the Access Agent utilizes the current ship characteristics as the existing constraint conditions, these changes will be reflected in the actions of the Stow Agent in automatic mode and the alerts provided by the Access Agent in manual mode.

**Hazardous Materials Agent:** The Hazard Agent verifies the proper placement of hazardous cargo items in reference to the various hazardous material codes and regulations discussed previously. It considers issues such as: Is the cargo item stowed in an acceptable location according to its stowage requirements? What are the segregation requirements for the cargo item, taking into account both the type of cargo item (e.g., break-bulk, container, vehicle) and the proximity of any other hazardous cargo items? In the case of containers, the Hazard Agent considers the hazard category of each item in the container in assessing the hazard condition of the container and its location relative to any other hazardous cargo item on the conveyance.

**Trim and Stability Agent:** The Trim and Stability Agent currently applies to ship conveyances only. It checks the placement of cargo items on the ship to see if they violate any desired (i.e., user specified) or mandated maximum draft settings, strengths (i.e., bending of the ship) or deck stress limitations. In automatic mode the Stow Agent will rearrange the placement of cargo during the Assisted Stow process if the placement of cargo causes the upper limits of the strengths properties of the ship to be exceeded. For example, if the predefined stow order requires the middle two stow areas of a deck to be stowed first and second, this would result in a *sagging* condition of the deck. Under these circumstances the Stow Agent will automatically re-define the stow order used by the Assisted-Stow process, so that the placement sequence of the cargo will begin with the forward and aft areas of the deck (thereby preventing the occurrence of the *sagging* condition).

ICODES calculates the effects of the exact placement of every cargo item stowed on the ship in three different planes. These planes are: forward to aft often referred to as the Longitudinally Center of Gravity (LCG); side to side or Transverse Center of Gravity (TCG); and, up and down or Vertical Center of Gravity (VCG). The Trim and Stability Agent takes into account the combined effects of all of the cargo items, the ballast, and the original condition of the ship to provide the user with fairly accurate estimates of the center of gravity in each of the three planes, as well as an overall assessment of the stability of the ship.

**Cargo Agent:** The Cargo Agent checks the characteristics of each cargo item against the expected characteristics for that cargo item as they are recorded in a number of reference

libraries including the Marine Equipment Characteristics File (MECF), the Joint Equipment Characteristics File (JECF), and other technical data cargo libraries. Not all cargo characteristics can be verified in this manner. While these cargo libraries currently contain more than 20,000 items, they are restricted in terms of the attributes that are provided for each cargo item. Typically, this verification process is complete and reliable only for dimensional (i.e., length, width and height) and weight attributes. If discrepancies are detected the Cargo Agent generates warnings.

### 3.4 Thick-Client User-Interface

Implemented in a typical Windows 2000 or XF operating system environment the main screen of the ICODES thick-client user-interface, as shown in Figure 5, consists of six components or sections.

(1) The *Main Menu Bar* provides access to the nine principal ICODES option groups in the form of pull-down menus. The option groups are: Loadout Plan; Ships; Cargo; Stow; Access; Stability; Tools; Window; and, Help.

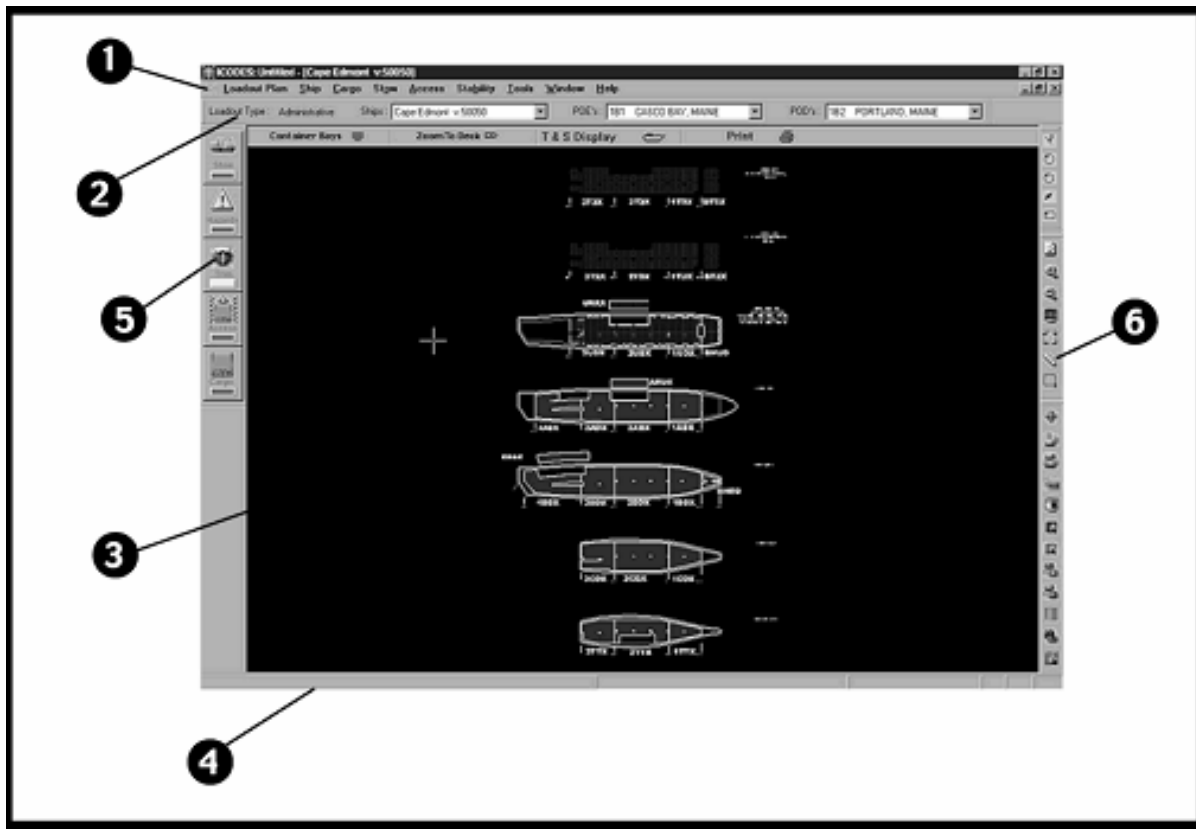


Figure 5: ICODES thick-client user-interface

(2) The *Loadout Plan* banner provides information about each of the currently displayed loadplans such as plan type(s), conveyance name(s), POE and POD, and the measurement units used in each plan.

(3) The *Graphics Window* displays the conveyance drawing(s). It can accommodate multiple conveyances, with the number that are concurrently displayed limited only by the constraints of the screen size and the memory capacity of the computer.

(4) The *Message Window*, found at the bottom of the main screen, provides the user with messages relating to the current status of ICODES (e.g., the status of an option selected by the user, or instructions relating to the use of a particular tool).

(5) The *Agent Status Bar* on the left side of the main screen provides access to agent reports and explanations of warnings and alerts.

(6) The *Tool Bars* on the right side of the main screen contain three groups of tools: stow tools (e.g., rotate, flip, unstow individual cargo items); view manipulation tools (e.g., zoom, pan); and, drawing tools that allow the user to superimpose lines, circles, polygons, and rectangles, on a displayed conveyance drawing.

ICODES offers a very comprehensive set of editing, saving, restoring, reporting, and special operations options (MTMC 2002). In addition, ICODES recognizes the differences among tactical (emphasizing mission accomplishment), pre-positioning (accommodating the maintenance requirements of pre-loaded regionally positioned conveyances) and administrative (focusing on the maximum utilization of troop and cargo space) load-plans.

The preparation of a load-plan can be undertaken in either of two modes. In the *User Stow* mode the user selects a cargo item from a textual cargo list, ICODES automatically converts the selected item into the appropriate graphic cargo symbol, and once the user has placed the cargo symbol in a stow area the agents assess the impact of the cargo item in that position on both the validity of the load-plan and the condition of the conveyance (in the case of a ship conveyance). The agents take into account: the path of the cargo item from the staging area to its final location on the conveyance (e.g., availability of ramps, cranes and elevators, and the dimensions of doors, hatches and openings); the segregation and other special requirements related to hazardous materials; and, the trim and stability conditions in the case of a ship.

In the *Assisted Stow* mode the user is able to define specific parameters at the cargo and conveyance levels and then request ICODES to automatically stow the cargo on one or more conveyances. Parameters include the establishment of preferences for individual stow areas, the exclusion of stow areas, the specification of spacing distances between cargo items, the orientation of cargo items, and the selection of subsets of the cargo list. Once the parameters have been specified (either by default or user selection) ICODES will automatically prepare a load-plan that does not violate any of the rules and regulations known by the agents.

The *Standard Reports* window provides pre-formatted reports used for specific purposes after a load-plan for a particular conveyance has been completed. These reports are different from those generated using the *Customize* feature in ICODES.

**Reports with user input:** Some of the Standard Reports provide text boxes allowing custom information to be entered, such as the names or contact information for personnel. These are provided for reports such as Cover Pages to specific reports or pages that must be signed to approve a plan.

**Reports requiring user selections:** Other Standard Reports are pre-formatted, but provide a way for the user to select specific information that should be included in a report. For instance, the user may wish to select the equipment of a specific military unit (i.e., by UIC) for inclusion in a report. Another example is to include in the report only the hazardous material loaded in just one stow area of the conveyance.

Each of the Standard Reports is different in terms of the information it provides. Below is a listing of each report and the information it provides. As indicated, some of these reports are appropriate for ship conveyances only.

**Association Report:** This report includes all of the cargo items stowed on a given conveyance that are part of a set of associations and item identifications that the user has selected. The UIC, Compartment, Nomenclature, TAMCN, Package ID, and Association Type are displayed for each item. .

**Assigned Report:** This report displays all of the items stowed on a given conveyance that are not displayed in the graphical representation (i.e., plan view) of the conveyance. In other words, items that have been stowed by Zone or Locker are included in this report. The UIC, NSN, Package ID, Item ID, Description, Templating Status, and Compartment are displayed for each item.

**Data Recap Report:** This report displays cargo grouped by JCS Cargo Category Code with one line for each JCS. The UIC, Quantity, Square Feet, Weight, M/T, and L/T are displayed for each line.

**Density Listing:** This report includes all of the cargo and personnel on a ship conveyance. The personnel are broken down into groups of officers, E7-E9, and enlisted personnel. Summarized cargo data are provided with UIC, Quantity, Description, and Unit of Issue displayed for each item.

**Embarkation Summary:** This report displays the cargo and personnel broken down by ship, with subtotals for each rank in the case of personnel. The information provided for each cargo item includes Ship Name, UIC, UPTT Code, and Quantity.

**Item Identification Reports:** There are two types of item identification reports for ship conveyances, each showing the same information but sorted by either Item Id or by Deck. Only cargo that is graphically displayed on the ship will be included in this report with Item ID, Description, Deck, and Count of Item Id displayed for each item.

**Ship Cargo Manifest:** This report shows all items stowed on the ship no matter how they have been stowed. The Ship, Compartment, Zone, Team, UIC, Landing Serial, Priority Order, UPTT, Association, Package ID/TCN, Parent Package ID, Item ID, JCS Cargo Category, Embark Category, Template Label, # Cargo, IMO Code, Length, Width, Height, Square Feet, Cubic Feet, and Gross Weight are displayed for each item in a three tiered line fashion.

**Ship Compartment Tonnage:** This report shows all items stowed graphically in the plan. The Ship, Compartment, Quantity, Cubic Feet, and Weight are displayed, summarized into one line for each compartment.

**Staging Report:** This report provides a listing of vehicles in reverse order compared to how they have been stowed in the plan. It allows the user to determine how cargo items should be moved aboard the vessel for deployment in the proper order. The Priority Order, Landing Serial, UIC, Package ID, Description, Height, Weight, and AIT Location Code are shown for each item.

### 3.5 Thin-Client User-Interface

The ICODES thin-client user-interface has been provided to satisfy the need for access to the information in ICODES load-plans by persons who do not have the ICODES application installed locally. These users may need to view the cargo on in-transit conveyances, or to examine past

shipments. Since users in this category have no need to modify load-plans, a straightforward read-only interface was considered to be the most appropriate solution. The ICODES thin-client is a web-based tool implemented as an Internet Explorer™ web browser. It is also available on the ICODES Web Site, where it can be readily accessed by any authorized user.

**Functional Aspects:** The ICODES Web Site allows authorized users to upload load-plans into a shared environment known as the ICODES File Share. This enables users to send load-plans from one POE to another, and to archive plans for future access.

The ICODES thin-client enhances this upload capability by extracting information from the load-plan and making this information available to an internal search engine. Once load-plans have been placed on the web site in the shared environment (i.e., ICODES File Share), the thin-client user-interface allows users to search for plans that contain a given ship, or include specific POEs and PODs, or were loaded within a specified period of time. Based on the results of these queries, users can select a particular load-plan for viewing.

Following the selection of a load-plan and conveyance, another web browser window opens. This window is divided into two sections. One section displays a graphical representation of the conveyance and its cargo, similar to the display of a conveyance in the ICODES thick-client. This display can be panned both horizontally and vertically, and there is a zoom function for expanding selected portions of the display. In the second section of the window there is a list of cargo items. This list can be sorted on several different attributes. Selecting a cargo item in the list highlights the symbol for that piece of cargo on the ship and vice versa, enabling users to locate specific items.

**Technical Aspects:** ICODES load-plans are Extensible Markup Language (XML) (<http://www.w3.org/XML/>) documents that represent all the information available to the ICODES suite of tools during the preparation of a load-plan. When a user uploads a load-plan to the ICODES File Share environment, the ICODES thin-client uses standard XML parsers and other tools to extract information from the file and place it in a database, making that information available for later use in the user-interface.

The thin-client user-interface employs a standard SAX (Simple API for XML) (<http://www.saxproject.org/>) parser to process the load-plan file. Instead of building a tree representation of an entire XML file in memory as a DOM (Document Object Model) (<http://www.w3.org/DOM/>) would do, a SAX parser identifies the individual parts of an XML document as it reads the file and immediately passes those parts to an object that implements the *org.xml.sax.ContentHandler*. When the parser identifies, for example, the start of an XML element and processes its attribute list, the parser will call the *ContentHandler.startElement* method, passing the element's name and the list of attributes as name/value pairs. SAX parsers eliminate the need to parse the entire document before processing can begin, which is important when dealing with very large XML documents like ICODES load-plans.

### 3.6 The ICODES Viewer

The ICODES Viewer was originally conceived to meet the demand of command officers to be able to look at the information in ICODES load-out plans without modifying them. The ICODES Viewer gives the user access to all of the reports and views available in ICODES but prevents the modification of data in the load-plan.

The design of the ICODES Viewer is very simple. The Viewer shares the same source code as the full ICODES application. However, when the Viewer version of the application is loaded the GUI classes activate checks that hide all of the functionality (i.e., menus and controls) that would normally allow users to modify the plan data. This simple design minimizes the software maintenance requirements by keeping the Viewer in sync with the main application as new functionality is added to the product.

### 3.7 The ICODES Observer

The ICODES Observer is a plug-in component designed to allow users to connect remotely to the main ICODES system. The Observer provides a read-only, dynamic view of an executing instance of ICODES, including, but not limited to, cargo, violations, and reports.

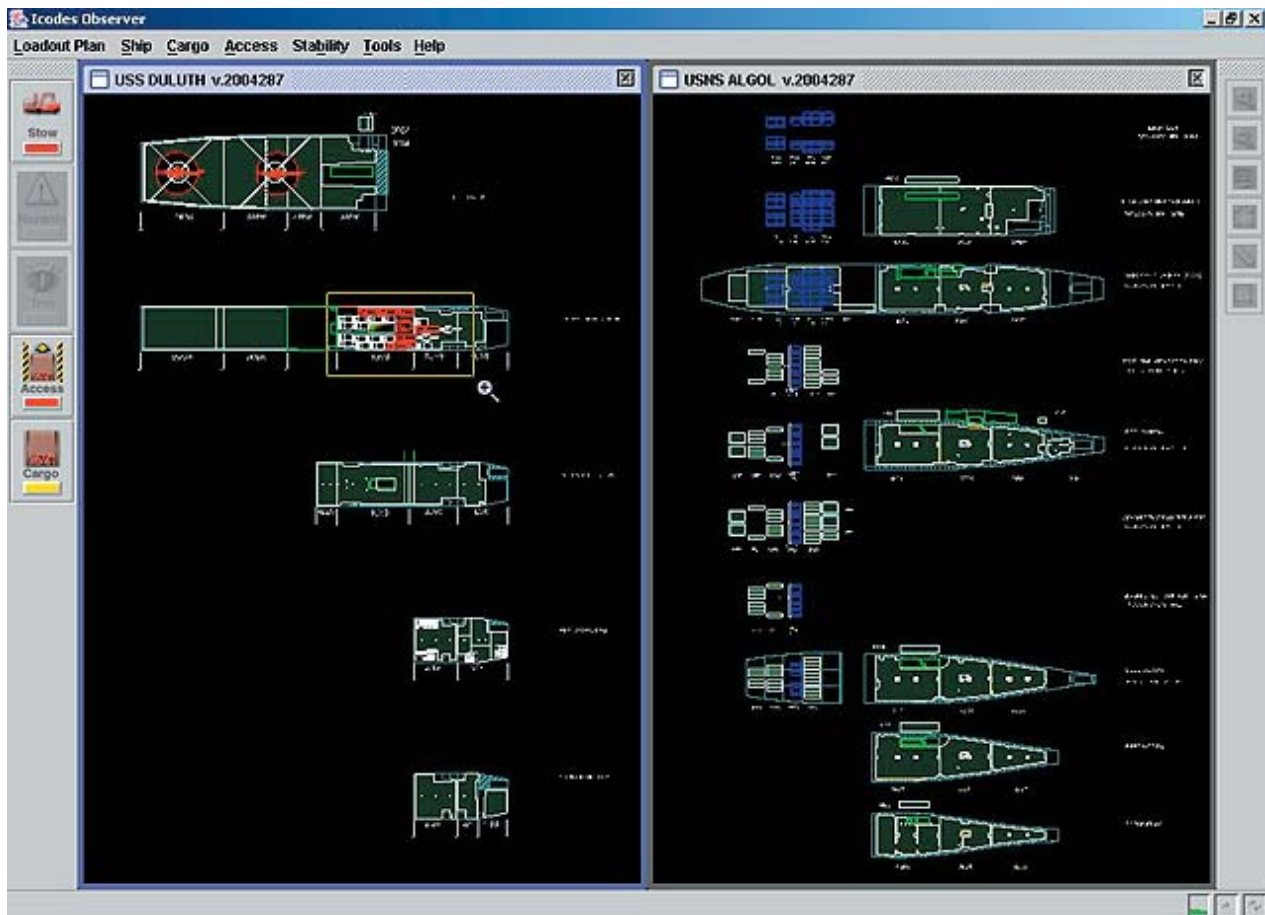


Figure 6: The ICODES Observer user-interface

Written in the Java programming language, the Observer communicates with ICODES through sockets and the ICODES External Systems Interface (IESI). The ICODES toolset includes several plug-ins for special purpose tools. They all connect to the IESI interface, utilizing the RSA<sup>5</sup> plug-in authentication procedure. Once connected, ICODES and the Observer communicate using XML messages in *broadcast* mode. Components in the Observer can subscribe to *broadcasts* for particular types of objects, corresponding to database tables in ICODES.

<sup>5</sup> RSA is an encryption technology developed by RSA Data Security, Inc. The acronym stands for Rivest, Shamir, and Adelman, the inventors of the technique.

A goal of the Observer's interface design was to mimic the ICODES thick-client user-interface, so that users familiar with ICODES would be able to understand the functionality and layout of the Observer with relative ease (Figure 6). The user has access to two toolbars, which mimic their corresponding ICODES counterparts, the *Agent Toolbar* and the *Viewer Toolbar*. The *Agent Toolbar* provides access to the violations maintained by each agent, while the *Viewer Toolbar* provides the ability to modify the viewing perspective, as well as measure areas and distances. The Observer also provides many of the same types of reports and information dialogs contained in the ICODES thick-client.

### 3.8 The JINNI Module

The JINNI module allows the user to build any kind of stow area from minimal data and simple paper sketches, for use in ICODES. Typical data requirements for a ship conveyance include: number of decks and holds; and, dimensions, shape, maximum allowable deck stress, and location of stow areas on each deck. JINNI incorporates a very powerful set of drawing and calculation tools based on the Generic Space Generator (GSG) component of the ICDM<sup>6</sup> development framework that forms the core of the ICODES suite of tools. Even though not all of the information and relationships that are available in a standard ICODES ship conveyance are included in a JINNI generated drawing (e.g., certain structural and hydrostatic data may not be available to the user), many of the reasoning functions provided by the Stow Agent, Cargo Agent and Access Agent will be operative.

The GSG<sup>7</sup> component of ICDM was designed as a client architecture for facilitating the rapid development of graphical user-interfaces. With its ability to harness the most recently released Open Graphics Library (OpenGL) calls from Java code, GSG is able to optimize performance for both two-dimensional and three-dimensional graphics requirements. The components of GSG are extensible and reusable to promote the rapid prototyping of applications that incorporate similar concepts.

JINNI allows the user to create spaces for a variety of goods transportation and management purposes such as truck beds, railcars, staging areas, marshalling yards, and even warehouses. The current version of JINNI utilizes ship terminology to describe these spaces (e.g., deck, stow area, ramp, etc.). However, planned future extensions will add modules to allow the use of nomenclature that is appropriate for the particular type of space under consideration. The construction of a space may be undertaken in any one of three alternative ways:

- A. By measuring 'x,y' coordinates on a scale drawing of the space and then entering these coordinates through the user-interface.
- B. By measuring the size of each area within a space on a scale drawing and then constructing each space individually so that these areas can be placed in their relative positions inside the space.
- C. By importing a digital picture (i.e., 'jpeg' or 'gif' image), setting the appropriate scale of the picture in JINNI, and then tracing over the image to construct the spaces.

Once spaces have been built, the following adjustments and additions can be made to these spaces:

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<sup>6</sup> The Integrated Cooperative Decision Making (ICDM) framework is a proprietary development toolkit for ontology-based multi-agent systems owned by CDM Technologies, Inc.

<sup>7</sup> GSG utilizes a custom Dynamic Link Library (DLL) in combination with Java Native Interface (JNI) technology to communicate directly with the available video card. Java JNI technology supports direct communication between Java and C++ as long as the necessary communications bridge is contained within the DLL.

- Adding fire lanes around the perimeter of the space at a user-specified distance (e.g., 3FT wide fire lane).
- Adding obstructions inside a constructed area such as walls, pipes, structural members, and so on.
- Adding notes and drawing shapes to further describe details of the spaces (i.e., lines, boxes, circles, and curves).
- Adding container cell to the constructed space to represent multiple levels of container stacks. Each cell allows a 20FT container or equivalent item (i.e. Tricon, Quadcon, etc) to *snap* into an appropriate location within the cell provided the dimensions are of a standard size.
- Adding *nodes* to existing shapes to adjust the number of line segments for a given shape. For example, if a given area has a cut-out due to an obstruction such as a fire hydrant, then additional nodes can be added and moved to change the boundary of the area to include the fire hydrant.

During the process of creating a space, the user has the ability to save the drawing to a file. Either the entire set of constructed spaces or an individual space can be saved for use at a later time, or for sending to another user. For example, the drawing of a previously constructed ship can serve as a template for the construction of another ship. The user can also *copy* and *paste* any number of objects to allow quick replication of similar objects. For example, lanes in a yard are often of a similar size; therefore, the drawing of one lane can be replicated to create a row of lanes.

Apart from the ICODES agents that are able to reason about load-planning concerns, JINNI itself incorporates agents that check for logical problems during the construction of a drawing. For example, these agents will warn the user if separate areas within a space have duplicate names, if such areas overlap, or if an area is not completely contained within the overall space. In addition to these agents, JINNI incorporates a number of *controllers* that ensure the geometric integrity of the drawing. They will attempt to correct user entry errors such as the placement of two nodes of an object in exactly the same location, as well as automatically manage the associations between different components of a drawing (e.g., between a deck and the stow areas on that deck, in the case of a ship conveyance). The final product of this process is an objectified space that can be loaded into ICODES and will be treated by the load-planning agents as if it were a ship conveyance.

### 3.9 Reference Libraries

The ICODES reference libraries provide access to existing reference data sets that catalog the static characteristics of identifiable data entities (i.e., encyclopedic data). These include data sets to characterize: standardized pieces of DoD equipment and supplies, hazardous material, explosives, and munitions. ICODES provides access to the reference libraries to allow:

- Users to browse, query, and print the data contained in a library from within ICODES.
- Users or agents to import data into the Cargo Semantic Network<sup>8</sup> from a standardized reference source.

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<sup>8</sup> The Semantic Network is the internal ontology that provides the necessary *context* for the reasoning capabilities of the ICODES agents. The Cargo Semantic Network is a domain within the ICODES ontology.

- Agents to validate data entered by the user, or imported from an external system, by comparison to the standardized data contained within the libraries.

For performance reasons the data contained in the libraries are not used directly by the Cargo Semantic Network. Instead, the libraries are used as sources of data that may be imported into the Cargo Semantic Network by the user or by agents. This allows large sets of reference data to be stored in relatively slow, but memory efficient, disk-based data structures, while the object representation resides entirely in memory for relatively fast access by users and agents alike.

The ICODES reference libraries are constructed from data sets made available by external organizations that have custodianship responsibilities. The construction process makes no modifications to the data values provided, with the exception of values that do not pass the validation criteria specified for the corresponding ICODES library attribute. Invalid values are supplied with an ICODES defined default value (essentially a NULL) of the appropriate type. The validation criteria used by ICODES depend on the attribute in use. This can range from a simple enumeration of all valid values to a regular expression describing the valid characters permitted in each position in the sequence of characters that make up the value. Attribute values that are considered incorrect by the users of ICODES, will not be modified during the construction process, nor will the latter add data records considered to be missing. These types of modifications *must* be made by the agency responsible for the data set, and will not be reflected in the ICODES reference libraries until after the source data used to construct the corresponding ICODES library have been updated. Efforts are under consideration to provide updates to the reference libraries on a more frequent basis than releases of ICODES.

The following reference libraries are currently supported by ICODES:.

**49 CFR Library:** Provides access to hazardous material reference data that have been cataloged by both the United Nations and the North American hazardous type identifiers. Since the source data are intended to present information to human users through a browser, they are not ideal for automated access or processing by computers. Therefore tools have been developed to convert the data into a format that is compatible with the ICODES toolset. It includes the following data elements (Table 1):

Table 1 - Reference Library 49 CFR Data Dictionary

| Attribute            | Type      | Description  |
|----------------------|-----------|--|
| UN Code              | string 6  | UN or NA hazardous type identifier   |
| Packing Group        | string 4  | Hazardous degree of danger   |
| Class                | string    | Hazardous classification code  |
| Division             | string    | Hazardous division   |
| IMO Code             | string    | International Maritime danger code, as derived from the Class, Division, and Compatibility Group attributes. |
| Label                | string    | Hazardous label  |
| Vessel Stowage Code  | character | Indicates permissible stowage locations  |
| Compatibility Group  | character | Hazardous compatibility group  |
| Proper Shipping Name | string    | Hazardous proper shipping name   |
| Special Provisions   | string    | Hazardous Special Provisions   |
| Other Provisions     | string    | Hazardous stowage requirements   |

**DCMNSN Library:** The DCMNSN Library provides access to reference data for mapping between hazardous material information and National Stock Numbers (NSN). It includes the following data elements (Table 2):

Table 2 – Reference Library *DCMNSN* Data Dictionary

| Attribute            | Type      | Description  |
|----------------------|-----------|--|
| NSN                  | string 13 | The National Stock Number  |
| Proper Shipping Name | string    | Hazardous proper shipping name   |
| DoDIC                | string    | DoD munitions identifier   |
| Hazard Class         | string    | <i>unknown</i>   |
| IMO Code             | string    | International Maritime danger code, as derived from the Class, Division, and Compatibility Group attributes. |
| Class                | string    | <b>HAZARDOUS MATERIAL CLASS</b>  |
| Division             | string    | Hazardous material division  |
| Compat Grp           | character | Hazard compatibility group   |
| UN Code              | string 6  | UN or NA hazardous type identifier   |
| Pack Group           | string    | Hazardous degree of danger   |
| Label                | string    | Hazardous label  |
| NEW/Round            | string    | The net explosive weight, per unit of issue, in pounds   |

**DoDIC Library:** The DoDIC Library provides access to reference data for explosives and munitions that have been cataloged by the DoD Identification Code (DoDIC). It includes the following data elements (Table 3):

Table 3 - Reference Library *DoDIC* Data Dictionary

| Attribute        | Type      | Description  |
|------------------|-----------|--|
| DoDIC            | string 4  | DoD munitions identifier   |
| UN Code          | string 6  | UN or NA hazardous type identifier   |
| Class            | character | Hazardous material class   |
| Division         | character | Hazardous material division  |
| Compat Grp       | character | Hazard compatibility group   |
| NEW/Round        | float 8   | The net explosive weight, per unit of issue, in pounds   |
| Nomenclature     | string    | The English text description corresponding to a particular DoDIC   |
| Ammunition Group | string    | Type of ammunition (fireworks or substance)  |
| IMO Code         | string    | International Maritime danger code, as derived from the Class, Division, and Compatibility Group attributes. |

**ECF Library:** The ECF Library provides access to reference data for military vehicles and equipment that have been cataloged by Model Number and Line Item Number (LIN). It includes the following data elements (Table 4):

Table 4 - Reference Library *ECF* Data Dictionary

| Attribute    | Type      | Description                                 |
|--------------|-----------|---|
| Model Number | string 12 | A standardized identifier for DoD equipment |

|             |                   |   |
|-------------|-------------------|---|
| NSN         | string 13         | The National Stock Number   |
| LIN         | string 6          | ECF Line Item Number; an ECF specific key used to locate the data records for a particular model                                  |
| LIN Index   | string 2          | ECF Line Item Index; an ECF specific key used to locate a specific data record from the set of data records identified by the LIN |
| Type Eqpt   | character         | A standardized coded identifier used to categorize equipment by type  |
| Length      | unit (distance) 8 | The bare (unloaded) length in inches  |
| Height      | unit (distance) 8 | The bare (unloaded) height in inches  |
| Width       | unit (distance) 8 | The bare (unloaded) width in inches   |
| Weight      | unit (weight) 8   | The bare (unloaded) weight in pounds  |
| Description | string 20         | The English text description which corresponds to a particular model.   |
| Shp Config  | string 2          | A coded ECF identifier for a particular shipping configuration  |
| Load Height | Unit (distance) 8 | The normal loaded height in inches  |
| Load Weight | unit (weight) 8   | The normal loaded weight in pounds  |

**IMDG Library:** The IMDG library provides access to the reference data for the International Maritime Dangerous Goods codes that have been collected by the International Maritime Organization (IMO). UN Code normally indexes this library. It includes the following data elements (Table 5):

Table 5 - Reference Library *IMDG* Data Dictionary

| Attribute            | Type      | Description  |
|----------------------|-----------|--|
| UN Code              | string 6  | UN or NA hazardous type identifier   |
| Class                | string    | Hazardous classification code  |
| Division             | string    | Hazardous division   |
| Proper Shipping Name | string    | Hazardous proper shipping name   |
| Flashpoint           | string    | Range of flashpoints   |
| Pack Group           | string    | Hazardous degree of danger   |
| Stowage Codes        | string    | Codes representing English stowage instructions. These codes are the keys in the IMDG Stow Codes Library.    |
| Compat Grp           | character | Hazard compatibility group   |
| Marine Pollutant     | string    | Indication of whether or not this material is a marine pollutant   |
| Vessel Stowage       | string 2  | Indicates permissible stowage locations  |
| IMO Code             | string    | International Maritime danger code, as derived from the Class, Division, and Compatibility Group attributes. |

**MECF Library:** The Marine Equipment Characteristics Library (MECF) provides access to reference data for US Marine Corps vehicles and equipment that have been cataloged by Model Number and Table of Authorized Material Control Number (TAMCN). It includes the following data elements (Table 5):

Table 6 - Reference Library *MECF* Data Dictionary

| Attribute          | Type                            | Description   |
|--------------------|---------------------------------|---|
| Item Id            | string 6                        | Table of Authorized Material and Equipment Control Number (TAMCN); a standardized USMC specific key used to identify a particular model |
| TAM Index          | string 2                        | MECF Line Item Index; an MECF specific key used to locate a specific data record from the set of data records identified by the Item Id |
| Supply Class       | character                       | JCS Supply Class Code; a standardized code which identifies a particular category for supply  |
| Description        | string 50                       | The English text description which corresponds to a particular model  |
| Logical Set        | character                       | Identifies if an entry is part of a logical set   |
| NSN                | string 13                       | The National Stock Number; a unique identifier to a particular type of DoD supply item  |
| Shp Config         | character                       | A coded MECF identifier for a particular shipping configuration   |
| Type Eqpt          | character                       | A standardized coded identifier used to categorize equipment by type  |
| Length             | unit <sup>8</sup><br>(distance) | The bare (unloaded) length in inches  |
| Width              | unit <sup>8</sup><br>(distance) | The bare (unloaded) width in inches   |
| Height             | unit <sup>8</sup><br>(distance) | The bare (unloaded) height in inches  |
| Weight             | unit <sup>8</sup><br>(weight)   | The bare (unloaded) weight in inches  |
| JCS Cargo Category | string 3                        | The JCS Cargo Category Code   |
| Model Number       | string 14                       | A standardized identifier for DoD equipment   |
| Load Length        | unit <sup>8</sup><br>(distance) | Length of the cargo bed in inches   |
| Load Width         | unit <sup>8</sup><br>(distance) | Width of the cargo bed in inches  |
| Load Height        | unit <sup>8</sup><br>(distance) | Height of the cargo bed in inches   |
| Load Weight        | unit <sup>8</sup><br>(weight)   | Maximum weight of cargo which may be loaded in pounds   |

**Tech Data Library:** The Tech Data Library provides access to reference data that have been cataloged by the National Stock Number (NSN) for use by the LOGAIS family of systems and TCAIMS-II. It includes the following data elements (Table 7):

Table 7 - Reference Library *Tech Data* Data Dictionary

| Attribute         | Type                          | Description  |
|-------------------|-------------------------------|--|
| NSN               | string 13                     | National Stock Number; a unique identifier to a particular type of DoD supply item                                   |
| NSN Configuration | string 15                     | English text which describes a particular shipping configuration, and corresponds to a particular Configuration Code |
| DoDIC             | string                        | The DoD Identification Code for munitions and explosives   |
| Nomenclature      | string                        | The English text description corresponding to a particular DoDIC.  |
| Weight            | unit <sup>8</sup><br>(weight) | The bare (unloaded) weight in pounds   |
| Length            | unit <sup>8</sup>             | The bare (unloaded) length in inches   |

|                      |                      |   |
|----------------------|----------------------|---|
|                      | (distance)           |   |
| Width                | unit<br>(distance) 8 | The bare (unloaded) width in inches   |
| Height               | unit<br>(distance) 8 | The bare (unloaded) height in inches  |
| Load Weight          | unit<br>(weight) 8   | Maximum weight of cargo which may be loaded   |
| Supply Class         | character            | JCS Supply Class Code; a standardized code which identifies a particular category for supply  |
| Unit Of Issue        | string 2             | A code which indicates the unit of issue  |
| JCS Cargo Category   | string 3             | The JCS Cargo Category Code   |
| Quantity Per Cargo   | string 5             | The number of separate components from which an item is comprised   |
| Model Number         | string 14            | A standardized identifier for DoD equipment   |
| UPTT Code            | string 2             | A code which characterizes an item within the Unit Personnel and Tonnage Table.   |
| Trn Radius           | integer 4            | The minimum turning radius of a vehicle in inches   |
| UN Code              | string               | UN hazardous type identifier  |
| NEW/Round            | unit<br>(weight) 8   | The net explosive weight of a munitions, per unit of issue, in pounds   |
| IMO Code             | string 4             | International Maritime danger code  |
| COMM                 | string 3             | The MILSTAMP commodity code for this item   |
| Hdlg                 | character            | The MILSTAMP special handling code  |
| Item Id              | string 10            | Table of Authorized Material and Equipment Control Number (TAMCN); a standardized USMC specific key used to identify a particular model |
| Proper Shipping Name | string               | Hazardous proper shipping name  |
| Description          | string               | The English text description which corresponds to a particular model.   |

**Symbol Lookup Library:** The Symbol Lookup Library provides a mapping between cargo types and the symbols used to visually represent them. While the ICODES toolset displays these symbols in its graphical load-plan displays, there are currently no facilities available for viewing the textual and numerical content of this library.<sup>9</sup> The attributes listed below are the attributes that would be visible if such a facility were available (Table 8)..

Table 8 - Reference Library *Symbol Lookup* Data Dictionary

| Attribute    | Type      | Description   |
|--------------|-----------|---|
| NSN          | string 13 | National Stock Number; a unique identifier to a particular type of DoD supply item  |
| Model Number | string 12 | Model Number attribute from the ECF Library. (Model Numbers listed in the MECF and Tech Data Libraries are not present in the Symbol Lookup Library.) |
| LIN          | string 6  | ECF Line Item Number; an ECF specific key used to locate the data records for a particular model in the ECF Library                                   |
| LIN Index    | string 2  | ECF Line Item Index; an ECF specific key used to locate a specific data record from the set of data records identified by the LIN                     |
| Item Id      | string 5  | Table of Authorized Material and Equipment Control Number (TAMCN); a standardized USMC specific key used to identify a particular model               |

<sup>9</sup> The reason is that there would be no purpose for the ICODES user to view the textual and numeric description of symbols.

|           |          |   |
|-----------|----------|---|
| TAM Index | string 2 | MECF Line Item Index; an MECF specific key used to locate a specific data record from the set of data records identified by the Item Id |
| Symbol    | string   | Name of symbol which can be used to visually represent this item  |

**Symbols Library:** The Symbols Library is a graphical library that provides objectified 2-D scale symbols of military cargo that are used in the templating of cargo during load-planning. The Symbols Library consists of 4000 cargo items and is available in both AutoCAD and OpenInventor file formats.

**Vessel Library:** The Vessel Library is a graphical library that provides objectified ship drawings and associated files for all ships commonly used in the military load-planning community. There are currently over 320 ships in the Vessel Library. CDM Technologies, Inc.<sup>10</sup> maintains the Vessel Library under contract to USTRANSCOM. It is accessible to authorized users over the Internet, so that military personnel can down-load the latest version of any ship for load-planning purposes. The ships are periodically surveyed by MARAD and changes transmitted to CDM Technologies for implementation.

**Water Ports Reference Data Table:** The latest Water Port Facility Text File in the USTRANSCOM Table Management Distribution System is ported over to the ICODES toolset on a weekly basis. The file is received via e-mail and then reformatted for automated comparison with the previous version currently resident in ICODES. Only if differences are detected between the two versions is the existing version replaced by the new version, in ICODES.

### 3.10 Data Import Requirements and Options

The ICODES toolset currently supports 178 attributes for each cargo item (Appendix A). However, only a subset of these attributes is typically included in the cargo lists that ICODES receives from external systems. The precise list of data elements that are exchanged with each external system is defined in the formal Interface Agreement for that particular system.

The minimum set of cargo attributes required for ICODES to be able to process a cargo list is different for Army and Marine Corps cargo lists, because the Marine Corps does not recognize TCN<sup>11</sup> as a cargo attribute. Since the Marine Corps does not have an equivalent single cargo item identifier, ICODES requires a combination of three data elements (i.e., UIC, NSN, and PKG ID) to establish the uniqueness of any particular Marine Corps cargo item. For either service additional attributes are required if hazardous material considerations are to be taken into account by the load-planning agents.

**Army Basic Minimum:** TCN, UIC, Bumper Number, Container Number, Container Owner, Model Number, Description, Length, Width, Height, Weight, Type Pack, POE, and POD.

**Army Hazardous Material Minimum:** UN Code, Pack Group, IMO Code, DoDIC, Rounds, Type Explosive, and Limited Quantity.

**Army Optional Attributes:** Booking Number, Voyage Document Number, Bed Height, Consignee, LIN, LIN Index, Remarks, and "Destination" (e.g., Fort Bliss for cargo being offloaded for onward movement).

<sup>10</sup> CDM Technologies, Inc. is the commercial arm of the CADRC Center at Cal Poly (San Luis Obispo).

<sup>11</sup> The 17-character Transportation Control Number (TCN) is the unique identifier for all in-transit Army cargo.

***Marine Corps Basic Minimum:*** UIC, NSN, PKG ID, Serial Number, NSN Configuration, Association, Parent NSN, Parent Package ID, Parent UIC, Container Number, Item ID, Description, Length, Width, Height, Weight, Pack Type (same as Type Pack), Geoloc Code, Mission Number, Team Name, Supply Class, UPTT Code, and Unit of Issue.

***Marine Corps Hazardous Material Minimum:*** UN Code, Pack Group, IMO Code, DoDIC, Ammunition Group, Rounds, Type Explosive, and Limited Quantity.

***Marine Corps Optional Attributes:*** Cap Set, Embark Category, ISO Container Number, LTI Code, JCS Cargo Category, Landing Serial, Offload Geoloc, Onload Geoloc, Priority Order, RUC, SUC, SL3, Tag, and Tag Id.

Strictly speaking the sets of *Basic Minimum* attributes listed above for the Army and the Marine Corps are practical minimum requirements based on operational considerations. Theoretically, the absolute minimum requirements would be satisfied by an attribute set that uniquely identifies the cargo item and describes its physical weight and dimensions. For the Army this minimum requirement is satisfied by five attributes, namely: TCN; Weight; Length; Width; and, Height. As mentioned previously, in the case of the Marine Corps three attributes are required for unique identification purposes (i.e., UIC, NSN, and PKG ID) for a total of seven attributes.

### **3.11 Hardware Requirements**

The recommended system software and hardware requirements for the ICODES toolset include the Windows 2000 or Windows XP Professional Operating System executing on:

- Single processor CPU operating at a minimum of 2 GHz (clock speed).
- Minimum of 1 GB of RAM (2 GB is preferable).
- Graphics card with at least 32 MB RAM.
- 20 GB disk drive (with a minimum 1 GB of available free space).
- 2X CD-ROM drive.

## 4. Capabilities of the TRANSWAY Toolset

The deployment and distribution responsibilities of USTRANSCOM call for intelligent collaborative tools in support of strategic and operational planning functions involving the sustainment and movement of forces. The sustainment requirement is generated at the operational level and is dynamic. It is composed of shifting priorities responding to changes in commander's intent and changes in the operational situation. However, while commander's intent and future plans normally drive the sustainment requirement, it is also possible for the reverse to occur. Unit movement and sustainment flow planning and execution monitoring is largely planned and executed at the strategic level, responding to ship and aircraft availability and other gross transportation factors only indirectly related to the changing operational priorities in the theater. Strategic flow planning and execution processes are focused on logistic efficiency and tonnage, while satisfying operational requirements is focused on logistic effectiveness (i.e., providing the right thing in the right quantity at the right place at the right time to the right units).

### 4.1 Extensible Functional Capabilities

TRANSWAY is designed as a set of intelligent collaborative tools (i.e., agents) supporting operators performing planning and re-planning tasks in a dynamically changing decision-making environment. Specifically, these agents are capable of generating optimized plans for the delivery of blocks of mixed supplies from multiple origins to multiple destinations within user-defined time windows and associated constraints. The agents consider alternative routes and multi-modal conveyance opportunities.

Currently (2006), TRANSWAY supports fixed wing aircraft (i.e., C-5, C-17 (military), C-130, Boeing 747, MD-11, and L-1101 (commercial)), helicopters (i.e., CH-47 and CH-53), truck convoys, and ships (i.e., Fast Sealift Ships (FSS), Large Medium-Speed Roll-On/Roll-Off (LMSR) ships, and commercial leased ships). Supply points (i.e., air and ocean POEs and PODs), distribution nodes (i.e., Theater Distribution Center (TDC), Joint Distribution Center (JDC), Corps Distribution Center (CDC), and Supply Support Activity (SSA)), and routes may be overlaid on scaled maps as automatically geo-referenced objects with attributes that can be reasoned about by the TRANSWAY agents. Context is provided by an internal ontology that is divided into logistical planning domains, and supports supply Classes I, V, and IX (partial) at Level 6 detail<sup>12</sup> loaded on standard 463L pallets<sup>13</sup>.

Parameters that may be set by the user before or during the generation of a delivery plan include the following:

- Geographic *inclusive* boundaries within which the agents are confined during the development of a delivery plan. These boundaries are drawn by the user directly on the displayed map and prohibit the agents from considering any resources (i.e., inventories of supply items and conveyances) or routes that are external to the bounded region.
- Geographic *exclusive* boundaries that exclude any resources (i.e., inventories of supply items, conveyances, and routes) within those boundaries to be considered during by the agents during the generation of a delivery plan. In the same way as *inclusive* boundaries, the *exclusive* boundaries are also simply drawn on the displayed map by the user.

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<sup>12</sup> Class I (Meals), Class V (Ammunition and Water) and Class IX (Repair Parts) at the individual cargo item level of detail.

<sup>13</sup> The standard 463L pallet measures 88" by 108" and weighs 290 lb (empty) plus 65 lb for netting for a total of 355 lb.

- Impediments that may either slow down the transportation of supplies or make certain types of conveyances unavailable. For example, a weather impediment may slow down a truck convoy, shut down an airport (APOE or APOD) that is scheduled for en route refueling, or reduce visibility below the level required for all or a particular type of aircraft. The user is able to specify the severity of an impediment.

The open, service-oriented architecture of TRANSWAY will allow these capabilities to be progressively extended. Planned extensions include additional decision-support tools that directly translate force and mission plans into statements of logistic requirements with associated inventory-based risks and opportunity costs.

## 4.2 Using the TRANSWAY Toolset

A comprehensive step-by-step demonstration scenario, including a representative set of reports, is included in Appendix B of this report. The demonstration scenario is executed on the TRANSWAY thick-client user-interface. A TRANSWAY thin-client user-interface is currently under development and is scheduled for release in December 2006.

## 4.3 Operational Interrelationships

An operational view of TRANSWAY's planning, re-planning and execution simulation capabilities is depicted in Figure 7 in terms of four principal activity areas: starting up and shutting down the system; defining and editing the environmental context of the application domain; displaying reports; and, creating plans based on initial and changing conditions.

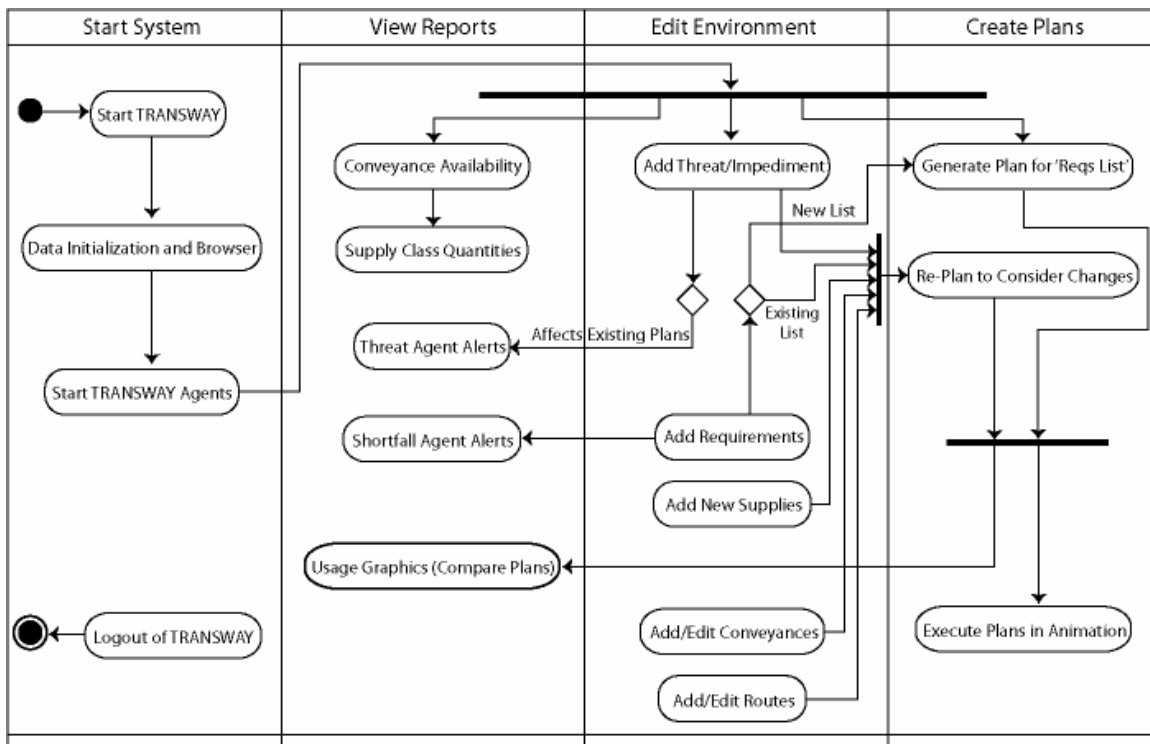


Figure 7: Typical TRANSWAY operational sequences

**Start-Up and Shut-Down:** After start-up, TRANSWAY provides options for importing sets of objectified CONUS and theater elements (e.g., SSA nodes, POEs and PODs, route legs, etc.) presenting their associated graphics as layers on automatically geo-referenced maps (Vector Product Format (VPF), Compressed ARC Digitized Raster Graphics (CADRG), and Controlled Image Base (CIB)). These objects, which may be alternatively entered and edited by the user, are represented as instances of the internal ontology providing context for the reasoning capabilities of the TRANSWAY decision-support agents.

A second component of the initialization process is the start-up of the TRANSWAY Agent Tier. This activity initializes the agents with appropriate context parameters. Once initialized the agents register their individual information interests with the *Subscription Service*. Upon satisfaction of such interests subscribers (i.e., agents, GUI components, etc.) are automatically notified of data changes and will react according to their business rules.

**Editing Theater Elements:** The user may add or change characteristics of the physical environment. Editable elements include the following:

- *Requirements:* The addition of a new list of requirements or changing an existing list by adding a new requirement, modifying an existing requirement (i.e., change quantity, change delivery time, change destination, etc.), or deleting an existing requirement.
- *Supplies:* The addition or deletion of inventory supplies to nodes.
- *Conveyances:* The addition, modification, or removal of conveyances from nodes.
- *Routes:* The addition, modification, or removal of routes from the environment.
- *Threats or impediments:* The addition, modification, or deletion of a threat or impediment indicator in the environment. The user may add an impediment by drawing a polygon to represent the area, which is affected by the threat or impediment.

**Displaying Reports:** Among the set of reports available in TRANSWAY are inventory, cargo, conveyance, and agent reports. Inventory reports show users the availability and status of supplies. Cargo reports show the status of outgoing supplies. Conveyance reports show the availability and status of conveyances at nodes. Produced through agent-based analysis, agent reports communicate various outstanding issues and recommendations to operators and other system components (e.g., other agents, external systems, etc.). Some of these reports identify issues with existing or evolving delivery plans, including inventory deficiencies or shortfalls and threats or impediments that impact the ability to execute an existing plan.

**Creating Plans:** This activity involves the specification or selection of a set of requirements that need to be satisfied along with various criteria that can help shape the resulting plan (e.g., priority for the conservation of transports or supply missions, strengthening or relaxation of certain delivery windows, and transport and supply center selection preferences). Once such criteria have been adequately specified the agent-based planning process can be initiated. The effectiveness of resulting plans can be compared through various reports. Apart from reflecting the effects of delivery plans actually executing within the theater, the impact of plans can also be explored through simulation.

Apart from specific planning criteria, plans are created based on the current state of available supplies, requests for supplies (i.e., requirements) that need to be satisfied, the priority of these requirements, the availability of conveyances, the nature of alternative routes, and the existence of any threats or impediments that may influence the selection of routes. Throughout the planning and plan-monitoring

process agents identify and communicate various issues (i.e., inventory and transport shortfalls, etc.) through the creation of agent alerts. An agent alert is also created to indicate the completion of the planning activity, so that operators are made aware of the state of concurrent planning activities in a distributed user environment.

#### 4.4 The TRANSWAY Agents

The TRANSWAY agents are required to have access to a wide array of information about: conveyances; cargo; requirements for supplies; locations; routes; and so on. Each of the various types of information contains limitations or constraints that determine behavior. For example, conveyances all have a maximum range and a cruising speed. This *context* is represented in the TRANSWAY, which allows the individual constraints to be added, deleted, or modified through the interaction of the user with the system.

The agents are highly responsive to system events. This is necessary so that changes in the route planning environment, either through user action or data imported from external systems, are immediately taken into account by the agents during the generation of plans. For example, if a route becomes unavailable due to weather or an enemy threat the agents are informed of the disabled route so that they can respond appropriately. A common practice for supporting this level of responsiveness in a Java development environment is to use Java Beans. A Java Bean provides a strategy for event-driven programming. The necessary event-driven environment has been implemented in TRANSWAY by encapsulating all of the properties of an object into a bean and notifying *listeners* when any of these properties have changed.

Since the TRANSWAY system incorporates many small agents that perform specific computational tasks, threading and synchronization required particular attention. Often several of these computational tasks need to be performed in parallel or, more accurately stated, cannot be performed serially. An example of this requirement for concurrency is the need for one agent to monitor the current demand for supplies, while another agent continually calculates the shortest path algorithm. The principal TRANSWAY agents incorporate the Tabu Search algorithm, which is a specialized implementation of genetic algorithm principles. A brief discussion of the criteria adopted for the design of the Tabu agents follows.

***Separation of Trip and Plan Generation:*** Based on a review of the literature it was decided early on in the design of the TRANSWAY agents to treat trip and plan generation as separate problems. This criterion was adopted as an important design feature of the Tabu agents, to limit the number of trips produced so that the combinations of trips that make up a better (i.e., more optimal) plan can be found more quickly.

***Selection of Search Methodology:*** With the separation of trip and plan generation the planning part becomes primarily a search problem. As new trips are generated they need to be considered as possible components of a recommended plan. However, even with the limitation of the search space through the application of constraints, the combination of generated trips into valid plans is likely to be time consuming. It was therefore decided that the TRANSWAY user should be provided with some means for controlling the number of plans generated by the agents. In TRANSWAY Version 1.0 this is accomplished by allowing the user to set a time limit at the beginning of the plan generation process, and by allowing the user to terminate the search process at will.

***Notion of a ‘Move’:*** Even though the Tabu Search methodology is particularly suitable for the

type of vehicle routing and scheduling problem encountered in the goods movement application domain, there was a need to translate the notion of a *move* into TRANSWAY's object-based representation. According to the Tabu Search methodology a *move* is typically defined as replacing one trip in the solution with another trip. However, a trip cannot be replaced by just any other trip. Therefore, some implementations of Tabu Search utilize the conveyance as a convenient identifier, so that one trip can be replaced by another trip if they share the same conveyance. This is not acceptable in the case of TRANSWAY because conveyances should be able to make more than one trip. Therefore, in TRANSWAY trips are identified by the degree to which the demand for supplies is satisfied. Accordingly, a set of trips can be replaced by another set of trips that satisfies all or a subset of the demands.

In the TRANSWAY implementation the Tabu agent attempts to find the best combination of trips that together form reasonable planning recommendations. The trips in this case are the atomic entities. The Tabu agent tries to add or remove trips during each iteration of the algorithm based on several strategies. It will first attempt to add trips to the current solution. If it cannot add more trips to its current solution it will remove trips and begin again. One fundamental aspect of a Tabu Search is its adaptive memory. By maintaining a list of taboo choices the Tabu agent is capable of diversifying its approach through the combinatorial solution space. When Tabu examines the various choices or trips that can be added to the current plan it first checks the taboo list to see if that solution has already been examined and chooses the best non-taboo option as the new incumbent solution. This approach allows the algorithm to search through a large combination of trips, while considering solutions that hold the most promise relatively quickly.

Using the Tabu agent TRANSWAY is able to find reasonable plans in a short amount of time and more optimal plans if it is allowed to continue running. Once some ending criterion has been reached the algorithm will stop and report the best solution that has been found. In TRANSWAY Version 1.0 reporting occurs on a continuous basis as better and better solutions are found. The user may stop the search at any time.

The implementation of the Tabu algorithm in TRANSWAY can be best described in terms of two principal design components, namely *services* and *agents*. In respect to *services*, an event manager receives events from the TRANSWAY ontology through the ICDM-based subscription service. Agents acting as listeners are able to register interest in these events, which are treated as services. The following *services* have been implemented in the current version of TRANSWAY:

***Request Service:*** This service maintains the locations, quantities, priorities, time windows, and types of supplies requested.

***Conveyance Service:*** This service maintains the current locations and capabilities of all of the conveyances within the AOR.

***Supply Service:*** This service maintains the locations, quantities, and types of supplies available.

***Routing Service:*** This service listens to changes within the graph-like structure of nodes and route segments. A shortest path matrix is maintained for each type of route traversal such as air, water, and land. Accordingly, agents are able to ask the routing service whether one or more routes exist between two nodes and, if yes: What is the shortest route? Agents may also ask the routing agent to compute shortest routes based on a maximum range between refueling stops.

Several kinds of *agents* with different functional responsibilities have been implemented in TRANSWAY to collaboratively develop strategic planning solutions, as follows:

**Generic Trip Generation Agents:** These agents generate a set of all possible trips that satisfy all of the business rule constraints. In this regard a generic trip is composed of a vehicle traveling to a supply depot, picking up supplies, delivering those supplies to another location, and returning to its home base. The following rules for trip generation have been implemented:

- A conveyance cannot exceed its range without refueling.
- A conveyance must travel on a route of its traversal type.
- A conveyance should try and take the shortest path when available.
- An impediment may cause the need for alternate routes.

**Convoy Building Agent:** This agent is responsible for constructing convoys out of trucks. The convoy then acts as another conveyance for the other agents to work with.

**Advanced Trip Generation Agents:** These agents take the single trips that have been generated and determine whether combining two or more of these trips could lead to greater efficiency. For example, two trips could be combined when they use the same conveyance and their time constraints are compatible. The user has some indirect control over the number of advanced trips to be considered by limiting the size of an ‘area of interest’. Events are received from either Java Bean property changes or the ICDM-based subscription service (Figure 8).

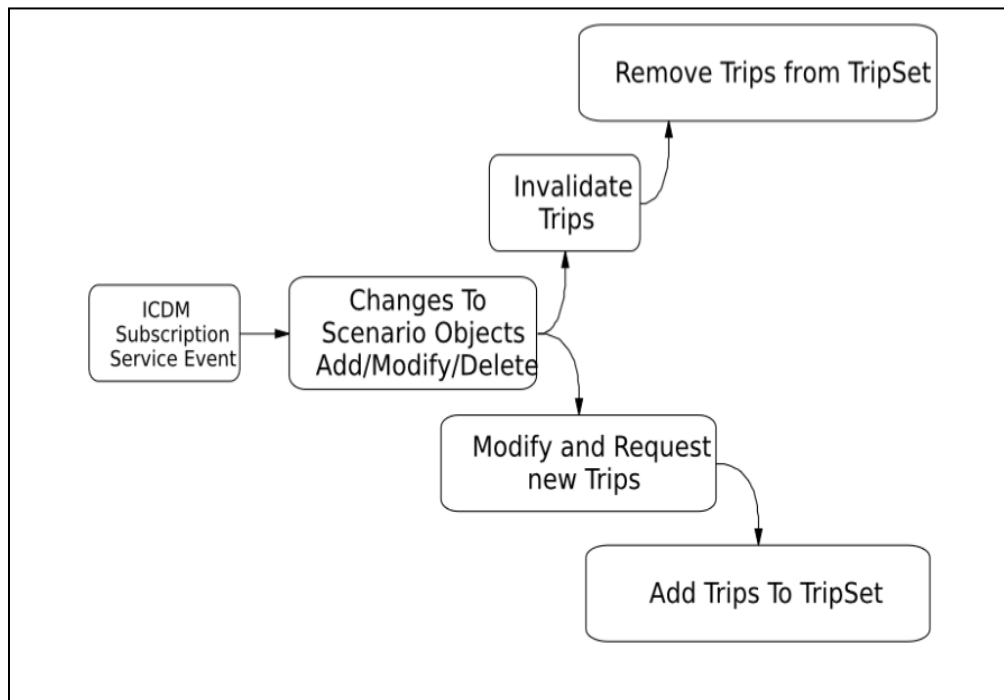


Figure 8: Trip generation flow diagram

**Plan Generator Agents:** The actual plan generation is performed with the Tabu Search method. A first plan will exist when the Plan Generator Agents begin their work. This plan may satisfy no demands or it could be a poor initial solution. As new trips become available they may be considered as part of the current plan. Being able to consider any partial solution as a position to work from promotes good dynamic behavior. It also allows Tabu Search to react to changes such as route impediments, and to invalidate parts of a plan while retaining other parts that may still be valid and useful. The following rules are applied for combining trips during plan generation:

- A Conveyance travels at the rate of its cruising speed.
- A Conveyance cannot carry more pallets than it has pallet positions for.
- A Conveyance cannot carry more than its weight limitations will allow.
- A Conveyance will attempt to avoid impediments unless the path is only partially blocked.
- A Conveyance will not travel when it is scheduled as unavailable.
- Aircraft at an airport will not exceed the working MOG limitation.
- Requested cargo will be delivered by the requested ETD and not after the requested LTD.
- All conveyances allow for a four-hour refueling time.
- Load and unloading times are added to each trip according to the user's input.
- A Conveyance cannot be in two places at once.
- No trips will be scheduled for departure before the current time plus the earliest plan commencement time.

Several features render the Tabu Search method implemented in TRANSWAY well suited for operational and strategic planning. The Tabu agents are able to deal with changes to the scenario dynamically while creating a plan. They do this by adjusting the current and best solutions to compensate for the change that took place. This allows the agents to retain much of the work that they have previously completed and build on it as they continue their work.

## **5. The ICODES-TRANSWAY Toolsets in an Experimental Exercise**

The proposed experimental demonstration of the SM21 Project follows a demonstration of the concepts of an Efficient Marine Terminal (EMT) and Agile Port System (APS) that was conducted at the Port of Tacoma, Washington, in 2003 within the context of a commercial-public transportation environment. EMT represented the marine terminal component of a postulated Efficient Marine/Rail Intermodal Interface (EMRII) system. The demonstration suggested that full implementation of the EMRII concepts and associated processes could conceivably achieve operating cost savings of approximately 40% (Savacool 2006).

The purpose of the SM21 demonstration planned for sometime during the first half of 2007 is to validate the findings of the 2003 demonstration with a full-scale implementation of the entire EMRII system. Specifically, it is proposed to utilize an integrated SM21 system platform in support of the deployment of a Brigade Combat Team from Fort Lewis to the Port of Tacoma through the commercial-public transportation corridor. The demonstration objectives include:

- Explore the integration requirements of military, commercial, and public transportation needs and expectations within the constraints of a commercial-public transportation corridor.
- Address the ability of a marine terminal to accommodate military load-out operations while minimizing disruption to commercial operations.
- Minimize the area of terminal real estate required during ship loading operations by reducing the total staging area requirement to no more than two acres.
- Conduct the military deployment operations through a commercial terminal in parallel with commercial container ship unloading and loading operations.
- Provide the ability to plan, track, and dynamically re-plan the force deployment from the garrison to the port.

As stated in the after-action report of the 2003 demonstration, it is proposed to: “...to construct and demonstrate a dynamic force deployment execution process planning that allows for dynamic re-planning of the PPP (Power Projection Platform) to strategic port movement of forces ...” (Savacool 2006).

### **5.1 The Exercise Scenario**

It is proposed to move an Army Brigade Combat Team (BCT), comprising approximately 3,000 soldiers with their organic equipment assets, from Ft. Lewis to the Port of Tacoma. Since Ft Lewis is located less than 20 miles from the Port, the movement will utilize truck convoys. The objective of the exercise is to accomplish this military movement as expeditiously and efficiently as possible with minimum disruption of vehicular traffic in the public transportation corridor and minimum impact on normal commercial port operations. Efficiencies and economies are expected to be achieved by:

- A. Utilizing to the extent possible commercial-of-the-shelf (COTS) and government-of-the-shelf (GOTS) software, integrated to facilitate the flow of data and thereby ensure the availability of a common operational picture throughout the exercise. This will require the seamless exchange of data between multiple software systems during the movement.
- B. Integrating existing military data feeds (e.g., TCAIMS-II) into the data flow, so that the data used in the SM21 system environment are compatible with and representative of standard

military logistic data. This will require the fusion of data received from separate military and commercial sources.

- C. Emphasizing pre-execution planning through early examination of data, anticipation of problem areas and potential failure points, and the development of contingency plans.
- D. Considering the vehicular traffic patterns in the affected portions of the public-commercial traffic corridor during the earliest planning stages.
- E. Considering the potential influence of the movement on the normal commercial port activities, and vice versa, during the earliest planning stages.
- F. Having available intelligent re-planning tools that will allow operators to prepare alternative plans in near real-time when unforeseen events occur during the execution phase.
- G. Reducing the marshalling yard footprint(s) required at Ft Lewis and at the Port of Tacoma, to the extent possible.
- H. Considering the loading sequence of the ship(s) at the port during planning of the marshalling yard(s) at Ft Lewis, the order of trucks and convoys, and the staging of equipment at the Port.
- I. Maintaining in-transit visibility throughout the movement from the marshalling yard(s) at Fort Lewis to the final location of the equipment and supplies on-board ship.
- J. Planning and executing concurrent ship loading operations at the Port, so that the loading time will be reduced through parallel loading operations performed by multiple Stevedore gangs on the same ship.
- K. Increasing the load-planning efficiency of truck and ship conveyances in terms of decreased plan preparation time, reduced human resource requirements, and superior storage space utilization.
- L. Increasing the security and force protection aspects of the movement through better planning, tighter control of processes, continuous monitoring and in-transit visibility, and faster reaction to unforeseen events.

The exercise is planned to be conducted under real world conditions during an actual force deployment, with normal coordination and controlling roles played by the military chain of command, the operational personnel of the Army's Surface Deployment and Distribution Command (SDDC)<sup>14</sup>, civilian supervisory port personnel, and local law enforcement authorities.

## **5.2 Applying the Capabilities of the ICODES-TRANSWAY Toolset**

The capabilities of the ICODES-TRANSWAY toolset, described in some detail in Sections 3 and 4 (and Appendix B) of this report, may be summarized as pertaining to the areas of:

- Exchanging data with several existing military data feeds (i.e., TCAIMS-II, WPS, IBS (receiving only), and MDSS-II).
- Preparing objectified spatial representations of marshalling yards, conveyances, and transportation routes (within a geo-spatial reference frame).

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<sup>14</sup> The Surface Deployment and Distribution Command (SDDC) serves concurrently as a subordinate command of the Army and a component command of USTRANSCOM.

- Preparing staging plans and conveyance load-plans, with consideration of data integrity, storage area accessibility, hazardous material requirements, and trim and stability concerns in the case of ships only.
- Planning of delivery routes involving roads, seaways, and air channels.
- Rapidly re-planning load-plans and delivery plans in near real-time under emergency and extenuating circumstances.
- Merging cargo list changes received from military data feeds with existing cargo data, on a continuous basis throughout the conduct of the exercise.
- Exporting the cargo data contained in final load-plans to military systems through the same data feeds that were previously employed to import cargo data into ICODES.

These capabilities are available to be utilized within the integrated SM21 software environment during the exercise in support of the following operational sequences and functional activities:

1. Importing an initial cargo list from the TCAIMS-II, WPS or MDSS-II military data feeds (see Sections 3.2 and 3.10, and Appendix A).
2. Validating the integrity and completeness of the imported cargo list by comparison with multiple reference libraries (see Section 3.9).
3. Preparing an objectified spatial representation of the marshalling yards at Ft Lewis and at the Port of Tacoma (see Section 3.8).
4. Preparing cargo staging plans for the marshalling yards at Ft Lewis and the Port of Tacoma (see Section 3.3).
5. Capturing data pertaining to cargo with PDAs utilizing barcode scanning devices in (secure) wireless communication environments.
6. Preparing an objectified spatial representation of one or more types of trucks (see Section 3.8).
7. Preparing load-plans for trucks and truck convoys (see Section 3.3).
8. Preparing delivery plans for the movement of truck convoys from Ft Lewis to the Port of Tacoma (see Section 4 and Appendix B).
9. Re-planning delivery routes in case of events that require alternative delivery plans (see Section 4 and Appendix B).
10. Preparing load-plans for the embarkation of cargo onto ships (see Sections 3.3 and 3.4).
11. Re-planning loads on conveyances during execution in case of events that require alternative load-plans (see Sections 3.3 and 3.4).
12. Merging cargo data imported from external military data feeds with existing cargo data in the SM21 system environment (see Section 3.2).
13. Exporting final load-plan data from the SM21 system environment to military systems via TCAIMS-II, WPS or MDSS-II (see Section 3.2).
14. Providing visual access to load-plan information throughout the exercise via web-based user-interfaces (see Sections 3.5 and 3.6).

15. Providing geo-spatial mapping capabilities for the visualization of infrastructure and routes from a global view down to street level detail (see Section 4 and Appendix B).

## Appendix A: ICODES Data Dictionary

| ICODES Name        | ICODES Type               | ICODES Data Domain   | ICODES Description  |
|--------------------|---------------------------|--|---|
| Acknowledged       | Boolean (uneditable)      | True/False   | Indicates whether user has acknowledged a cargo item's violation or warning in an agent report since it was generated, Yes or No.   |
| AIT Location Code  | String (editable)         | Any string   | Automated Information Technology Location code. This code is generated by LOGMARS Labels.   |
| Ammunition Group   | String (editable)         | Any string   | Code used to indicate what Ammunition Group a given DoDIC belongs to (I.e., AA, BB, CC, DD, FF, GG, Inert or any combination).  |
| Area               | Double                    | Lower Limit = 0, Precision = 0   | The area of the rectangle bounding the footprint of the item.   |
| Asset              | String (uneditable)       | Any string   | The type of carrier or asset of cargo items such as a ship or helicopter.   |
| Assisted Stow Area | String (fixed length,[4]) | {ABCDEFGHIJKLMNQRSTUUVWXYZ1234567890}  | Used for identifying the stow area or compartment that a particular cargo item has been assigned to. Also used for importing stow area information from WPS to do an As Loaded Plan.  |
| Assisted Stow Ship | String                    | Any string   | Used for identifying the ship that a particular cargo item has been assigned to.  |
| Assisted Stow Zone | String                    | Any string   | Used for identifying the zone that a particular cargo item has been assigned to.  |
| Assoc. Height      | Float (editable)          | Lower Limit = 0, Upper Limit = 999, Precision = 0  | The adjusted height of the parent for a particular association as a result of taking the dimensions of the children.  |
| Assoc. L/T         | Float                     | Precision = 2  | Long Tons calculated based on the Assoc. Weight of the cargo item.  |
| Assoc. Length      | Float (editable)          | Lower Limit=0, Upper Limit = 99999, Precision=0  | The adjusted length of the parent for a particular association as a result of taking the dimensions of the children.  |
| Assoc. M/T         | Double                    | Precision=2  | Measurement Tons calculated based on the Assoc. Length, Assoc. Width, and Assoc. Height of the cargo item.  |
| Assoc. Weight      | float (editable)          | Lower Limit=0, Upper Limit = 9999999, Precision=0  | The adjusted weight of the parent for a particular association as a result of taking on the dimensions of the children.   |
| Assoc. Width       | float (editable)          | Lower Limit=0, Upper Limit=9999, Precision=0   | The adjusted width of the parent for a particular association as a result of taking on the dimensions of the children.  |
| Association        | Character (static)        | Hitched, Inventoried, Load Onto, Mobile Loaded, Palletized Put Into, Set, Stacked, Parent, None, | A link made between two or more cargo items, known as the children and another cargo item, known as the parent.   |
| Baplie Cell Number | String (uneditable)       | Any String   | Container Cell Identification as defined in the UN/EDIFACT Bayplan Message v3.1, section c517 .e3225 per the ISO-format, as provided by MARAD. This format defines container cells using a Bay/Row/Tier convention with 3 positions for the Bay/Row and 2 positions for the Tier (BBBRRRTT). When a Bay Number is less than 3 characters leading zeroes are provided (I.e., 0340210). Where athwart ship containers are present on a vessel the BAPLIE enumeration will define the first digit of a stack (I.e., this would be 5 in a Baplie Cell Number of 5340210). |
| Bed Height         | Float                     | Lower Limit=0, Upper Limit=9999, Precision=0   | The height of the bed floor surface of a truck or trailer floor surface of a trailer.   |
| Booking #          | String (editable,[4])     | [ABEFGHJKMNPQ][0-9], all caps  | Identifies a group of items intended to be stowed on the same ship  |

|                     |                                    |  |  |
|---------------------|------------------------------------|--|--|
| Bumper #            | String (editable)                  | Any string                                     | Vehicle bumper number stenciled onto vehicle bumpers. Determined locally.  |
| Cap Set             | String (uneditable)                | Any string                                     | No description available.  |
| Cargo Type          | Character (static)                 | Break-bulk, Container, Unknown, Vehicle,       | An ICODES generated code based on TCN, Type Pack and JCS Cargo Category Code to determine type of cargo a given items is (I.e. break-bulk, container, vehicle) |
| CIIC                | Character                          | [CJPSU12345678]                                | Control item inventory code.   |
| Class               | Short                              | None, [1-9]                                    | United Nations hazardous cargo class used in conjunction with Division.  |
| COMM                | String (editable)                  | Any string                                     | MILSTAMP commodity code.   |
| Compartment         | String (uneditable)                | Any string                                     | A stowable area based on the deck/hold combination and always matches the attribute Stow Area.   |
| Compat Grp          | Character (uneditable)             | { ABCDEFGHIJKLNS}                              | Ammunition compatibility group code.   |
| Consignee           | String (editable, fixed length[6]) | Any string, 6 char                             | A Unit Identifier Code used for cargo items placed on a Preposition Ship as they do not belong to a specific unity within DoD.                                 |
| Container #         | String (editable)                  | Any string                                     | MILSTAMP container number. A numbered code used to identify specific containers, utilized pallets or RORO trailers.  |
| Container Owner     | String (editable, fixed length)    | Any string                                     | The owner of a container regardless of the ocean carrier that moves it.  |
| Coverage            | enumerated type (editable)         | Unknown, N/A, Open, Closed                     | A hazardous attribute identifying the type of coverage for a particular cargo item (I.e., Unknown, N/A, Open or Closed.  |
| Cube                | Integer (editable)                 | Any int  | The number of cubic inches or cubic centimeters for a particular cargo item.   |
| Custody Code        | String (uneditable)                | Any string                                     | No description available.  |
| Date and Time Group | String (uneditable)                | Any string                                     | Indicates when an action occurred by date and time.  |
| Density             | Float                              | Precision=2                                    | Density of the item, calculated by weight divided by volume.   |
| Description         | String (editable)                  | Any string                                     | Text description of a Model Number or Item ID.   |
| Division            | Short                              | None, 1,2,3,4,5,6                              | United Nations hazardous division used in conjunction with Class.  |
| DoDIC               | String (editable)                  | Any string                                     | DoD Identification Code.   |
| Dot Class           | Character (editable,1)             | {ABCDEFGHIJKLMNQRSTU VWXYZ1234567890}          | Department of Transportation Class for a particular cargo item.  |
| Embark Category     | Character (editable, 1)            | {ABCDEFGHIJKLMNQRSTU VWXYZ1234567890}          | A code used to identify the Cargo Embarkation Category for a particular item.  |
| Exp Date            | Unsigned Long                      | Date   | A date used to identify the end of the usable life for a particular cargo item.  |
| Flash Point         | String                             | Any string                                     | The temperature where a given material can be ignited.   |
| Geoloc Code         | String (fixed length[4], editable) | Any string, 4 char                             | Geographical Location Code used to indicate a location on the globe.   |
| Haz Vol             | Double                             | Lower Limit=0, Upper Limit=999999, Precision=0 | The volume of a specific hazardous material within the cargo item, in quarts or liters.  |
| Haz Wt              | Double                             | Lower Limit=0, Upper Limit=999999, Precision=0 | The weight of a specific hazardous material within the carog item, in pounds or kilograms.   |
| Hdlg                | Character (editable)               | Precision=0                                    | MILSTAMP special handling requirement.   |
| Height              | Float                              | Lower Limit=0, Upper Limit=9999, Precision=0   | The height of an item in inches or centimeters.  |
| IMDG Page No.       | String (uneditable)                | Any string                                     | The page number in the IMDG where the information for a particular UN Code can be found.   |

|                    |                                   |  |  |
|--------------------|-----------------------------------|--|--|
| IMO Code           | String (uneditable)               | Any string                                     | The code used to identify the International Maritime Organization Class, Division and Compatibility Group for a particular UN Code.  |
| IMO Code List      | String (uneditable)               | Any string                                     | A series of IMO Codes indicating each unique IMO Code inside of a multiple hazard cargo item in ICODES. This attribute is not editable and is only used for cargo items with more than one UN Code attached to them. |
| ISO Container #    | String (editable)                 | Any string                                     | A number given to a container build according to International Standard Organization specification.  |
| Item #             | String                            | Any string                                     | User-defined data for grouping break-bulk cargo.   |
| Item Count         | Integer (editable)                | Lower Limit=1                                  | The number of accountable items represented by this item.  |
| Item Id            | String (editable)                 | Any string                                     | A code used to identify a particular type of cargo item in the USMC in a manner similar to how the U.S. Army uses model number.  |
| JCS Cargo Category | String (fixed length[3],editable) | Any string, 3 char                             | Joint Chiefs of Staff Cargo Category Code.   |
| L /T               | Float                             | Precision=2                                    | The weight of an item in long tons, regardless of measurement system (1 long ton = 2240 pounds)  |
| Label              | String (uneditable)               | Any string                                     | Hazardous warning label(s)   |
| Landing Serial     | String ([4],editable)             | Any string, <= 4 char                          | A unique four digit code that is assigned to the personnel and cargo items for a particular unit for landing.  |
| Length             | Float                             | Lower Limit=0, Upper Limit=999999, Precision=0 | Maximum length of the item in inches or centimeters.   |
| Limited Qty        | Boolean (editable)                | True/False                                     | A number of pounds or kilograms for a particular hazardous item. When the total number of pounds or kilograms is less than the Limited Qty, then that item is not considered for hazardous segregations.             |
| LIN                | String (editable)                 | (AF CB YU YA  ([A-NP-Z][0-9])) [0-9]{4}        | Line Item Number, used to reference Model Number entries.  |
| LIN Index          | String (editable)                 | Any string                                     | Used in conjunction with LIN as a unique key for identifying an entry in the model library.  |
| Load Height        | Float                             | Lower Limit=0, Upper Limit=9999, Precision=0   | The maximum loading height of the equipment in inches or centimeters.  |
| Load Length        | Float                             | Lower Limit=0, Upper Limit=999999, Precision=0 | The maximum loading length of the equipment in inches or centimeters.  |
| Load Weight        | Double                            | Lower Limit=0, Upper Limit=999999, Precision=0 | The maximum loading weight of the equipment in pounds or kilograms.  |
| Load Width         | Float                             | Lower Limit=0, Upper Limit=9999, Precision=0   | The maximum loading width of the equipment in inches or centimeters.   |
| Logical Set        | String (editable)                 | Any string                                     | An indicator or name given to a group of cargo items which stay together.  |
| LTI Code           | Character (editable,[1])          | {ABCDEFGHIJKLMN OPQRSTU VWXYZ1234567890}       | The Limited Technical Inspection Code used for a particular cargo item.  |
| M.T.               | Double                            | Precision=2                                    | Weight of an item in metric tons, regardless of the measurement system.  |
| M/T                | Double                            | Lower Limit=0, Precision=2                     | Volume of the item in measurement tons (40 cubic feet), regardless of the measurement system.  |
| Manufacture Code   | String (uneditable)               | Any string                                     | A specific code assigned to a given manufacture.   |
| Manufacture Date   | String (uneditable)               | Any string                                     | No description available.  |
| Marine Pollutant   | String                            | Any string                                     | A material, even when diluted to 10 of the original mixture that is considered to be dangerous, hazardous, and/or harmful to marine life.  |

|                      |                                      |  |   |
|----------------------|--------------------------------------|--|---|
| MILSTAMP Cell Number | String (editable)                    | Any string   | Container Cell Identification as defined in the Defense Transportation Regulations, Appendix V, Vessel Stowage Location Codes, as provided by MARAD. This format defines container cells using a Hatch/Bay/ Row/Tier (HBRT) convention with one position for each identifier. When the count of hatch, bay, row, or tier exceeds 9 , letters are used beyond this point (i.e., "B" means 11). |
| Mission Number       | String (editable)                    | Any string   | A code that is assigned to a particular mission.  |
| Mode                 | Character (editable,[1])             | {ABCDEFGHIJKLMNQRSTUUVWXYZ1234567890}                | MILSTAMP code identity; mode of shipment.   |
| Model Number         | String (editable)                    | Any string   | The Model Number description for an NSN (I.e., M998)  |
| MSE                  | String (editable)                    | Any string   | The Major Subordinate Element in a particular MAGTF   |
| Mstat                | Character (editable,[1])             | {ABCDEFGHIJKLMNQRSTUUVWXYZ1234567890}                | A code used to identify the status of a particular mission.   |
| NEW/Round            | Float                                | Precision=6  | Net explosive weight per round, in pounds or kilograms.   |
| Nomenclature         | String                               | Any string   | Text description of ammunition corresponding to a particular DoDIC.   |
| NSN                  | String (fixed length, [13],editable) | Any string, 13 char                                  | The NSN consists of the applicable four digit federal supply classification code (FCS) and nine digit serial number that fixes the identity to the particular item of supply.   |
| NSN Configuration    | String (editable)                    | Any string   | Identifies the configuration of a particular NSN.   |
| Offload Geoloc       | String (fixed length [4], editable)  | Any string, 4 char                                   | The Geographical Location Code for the location where cargo is to be offloaded.   |
| On Prty              | Integer (editable)                   | Lower Limit=0  | Code used to indicate priority cargo during on-load.  |
| Onload Geoloc        | String (fixed length[4], editable)   | Any string, 4 char                                   | The Geographical Location Code for the location where cargo is to be on-loaded.   |
| Other Provisions     | String                               | Any string   | Other HazMat stowage requirements.  |
| Overlap              | Float                                | Lower Limit=-999999, Upper Limit=999999, Precision=0 | The number of inches or centimeters that cargo items, in particular Hitched association, are suppose to overlap.  |
| P TCN                | String (fixed length)                | Any string   | The TCN of the Parent for a particular Association is entered by ICODES into this attribute for all children of that parent.  |
| Pack Group           | enumerated type (editable)           | None, I, II, III                                     | United Nations Packing Group, the degree of danger presented by the material; I, II, III or None.   |
| Package Lot Number   | String (editable)                    | Any string   | A lot number assigned by the manufacturer for a particular cargo item.  |
| Packing Certificate  | String (editable)                    | Any string   | User-defined palletization and storage data for hazardous cargo.  |
| Parent Pkg Id        | String                               | Any string   | The Package ID of the Parent for a particular Association is entered by ICODES into this attribute for all children of that parent.   |
| Parent Pkg NSN       | String (fixed length [13], editable) | Any string, 13 char                                  | The NSN of the Parent for a particular Association is entered by ICODES into this attribute for all children of that parent.  |
| Parent Pkg UIC       | String (editable)                    | Any string   | The UIC of the Parent for a particular Association is entered by ICODES into this attribute for all children of that parent.  |
| Pkg Id               | String (editable)                    | Any string   | Identifier for individual ship unit pieces.   |
| Placement Status     | Boolean                              | True/False   | Used in the Cargo Break-bulk window to indicate if a cargo item has been graphically placed inside of a break-bulk group. Has a value of Yes when the item has been placed and a value of No when the item has not been placed.   |
| Plan Id              | String (editable)                    | Any string   | This is the code used by LOGAIS in the database identifying all of the records belonging to a particular plan.  |

|                      |                                     |                    |   |
|----------------------|-------------------------------------|--------------------|---|
| POD                  | String (fixed length[3], editable)  | Any string, 3 char | Point of Debarkation, destination port.   |
| POE                  | String (fixed length[3], editable)  | Any string, 3 char | Point of Embarkation.   |
| Primary Explosives   |                                     |                    | This is a calculated value for items containing only class 1 hazardous data to display the "most hazardous" or "highest hazard" information for that item.            |
| Pre Ship             | String (editable)                   | Any string         | Used for identifying the planned ship that a particular cargo item has been assigned to.  |
| Pre Stow Area        | String (fixed length [4],editable)  | Any string, 4 char | Used for identifying the stow area that a particular cargo item has been assigned to. Also used for importing stow area information from WPS to do an As Loaded Plan. |
| Pre Zone             | String (editable)                   | Any string         | Used for identifying the zone that a particular cargo item has been assigned to.  |
| Priority Order       | Integer (editable)                  | Lower Limit=0      | Code used to identify what priority order a particular cargo item has in the offload sequence.  |
| Problem              | String (uneditable)                 | Any string         | Indicates the item's severity of conflict in an agent report, warning or violation.   |
| Proper Shipping Name | String (editable)                   | Any string         | MILSTAMP proper shipping name, a standardized name given to a specific hazardous material.  |
| Quantity             | Integer                             | Lower Limit = 0    | The number of items.  |
| QuantityPer Cargo    |                                     |                    | This is the same thing as Item Count and indicates how many of a given component are found within a cargo item.   |
| Rail Head            | String (editable)                   | Any string         | Shipping origin.  |
| Registration #       | String (editable)                   | Any string         | Vehicle registration number.  |
| Remarks              | String (editable)                   | Any string         | Information that is entered by the ICODES user or imported from WPS.  |
| Rounds               | Integer (editable)                  | Lower Limit=0      | The number of rounds in an ammunition shipment unit.  |
| Rstat                | Character (editable, [1])           | [1456789]          | Shipment unit status code.  |
| RUC                  | String (uneditable)                 | Any string         | Reporting Unit Code. This is the UIC that a given unit is reporting to.   |
| Seal #               | String (editable)                   | Any string         | A code used to identify the transportation equipment seal used for a particular item.   |
| Secondary Class      | Short                               | None, [1-9]        | United Nations hazardous cargo class used in conjunction with Division.   |
| Secondary Division   | Short                               | None,1,2,3,4,5,6   | United Nations hazardous division used in conjunction with Class.   |
| Secondary IMO Code   | String (uneditable)                 | Any string         | The code used to identify the International Maritime Organization Class, Division and Compatibility Group for a particular UN Code.                                   |
| Section              | String (fixed length [3], editable) | Any string, 3 char | A code used to identify a section within a particular unit.   |
| Sequence #           | Integer (editable)                  | Lower Limit=0      | A code used to identify where a particular cargo item fits into a particular sequence of cargo items or events.   |
| Serial Number        | String (editable)                   | Any string         | Vehicle serial number or user defined identities.   |
| Service              | String (fixed length [2], editable) | Any string, 2 char | An organization code identifying a specific armed-service organization within DoD.  |
| Shelf Life Code      | String (uneditable)                 | Any string         | Specific code used to indicate how long a given item will last when stored.   |
| Ship                 | String                              | Any string         | Name of ship or barge intended for use.   |
| Ship Cell Number     | String (uneditable)                 | Any string         | A ship specific cell number obtained from MARAD data  |
| Shp Config           | String (editable)                   | Any string         | Shipping configuration code.  |
| SL3                  | String (uneditable)                 | Any string         | Stock Listing 3 code used to identify a type of item or material.   |
| Spcl Hdlg Type Water | String (uneditable)                 | Any string         | No description available.   |

|                    |                                      |   |  |
|--------------------|--------------------------------------|---|--|
| Spcl Hdg Water     | String (uneditable)                  | Any string                                      | No description available.  |
| Spcl Provisions    | String                               | Any string                                      | HazMat special provisions for a particular UN Code.  |
| Spcl Stowage       | String (editable)                    | Any string                                      | HazMat special stowage provisions for a particular UN Code.  |
| Stack Limit        | Integer (editable)                   | Lower Limit=0, Upper Limit=99                   | The maximum number of cargo items that can be stacked on top of one another.   |
| Stow Area          | String (fixed length,[4])            | {ABCDEFGHIJKLMNQRSTU VWXYZ1234567890}           | MILSTAMP code of stow area.  |
| Stow Height        | Float                                | Lower Limit=0, Upper Limit=9999, Precision=0    | The height of a particular cargo item when it is stowed.   |
| Stow Weight        | Float                                | Lower Limit=0, Upper Limit=9999999, Precision=0 | The weight of a particular item when it is stowed.   |
| Stowable           | Boolean                              | True/False                                      | Indicates whether the item is stowable according to the Cargo Agent, either Yes or No. If any of the dimensions or weight equal zero, Stowable will be No.   |
| Stowage Codes      | String (uneditable)                  | Any string                                      | ICODES-specific codes used to reference the Stowage Codes found in the IMDG.   |
| Stowed             | Boolean                              | True/False                                      | Whether the item has been stowed or not, either Yes or No.   |
| SUC                | String (uneditable)                  | Any string                                      | Supporting Unit Code. This is the UIC that a given unit is supporting.   |
| Supply Class       | Character (editable,[1])             | {ABCDEFGHIJKLMNQRSTU VWXYZ1234567890}           | Identifies the Supply Class Code (i.e., A, 2, or 7)  |
| Symbol Name        | String                               | Any string                                      | Indicates the name of the symbol that is used to graphically represent a stowed cargo item. For example, if you want a stowed item to look like a trailer, you could key in M101 and that item will appear as a M101 trailer in the Graphics Window. |
| Symbol Type        |                                      | Symbol, Box                                     | Indicates the type of symbol that is used to graphically depict a stowed cargo item. Symbol means there is a detailed symbol while Box indicates a box is used.  |
| Tag                | Character (editable,[1])             | {ABCDEFGHIJKLMNQRSTU VWXYZ1234567890}           | USMC attribute related to AIT  |
| Tag Id             | Integer (editable)                   | Lower Limit=0, Upper Limit=9999                 | USMC attribute related to AIT  |
| TAM Control Number | String (editable)                    | Any string                                      | No description available.  |
| TAM Index          | String (editable)                    | Any string                                      | Table of Authorized Material Index Code (i.e., 01,03 or 07)  |
| Target Utilization | Float                                | Percent   | Percentage describing how much the break-bulk group volume to use.   |
| TCN                | String (fixed length [17], editable) | Any string, 17 char                             | MILSTAMP transportation control number.  |
| Team Name          | String (editable)                    | Any string                                      | Name given to all cargo assigned to a particular Amphibious Assault Ship.  |
| Templating Status  | Enumerated type                      | Assigned, Templated, None                       | Used to indicate how a particular cargo item has been stowed aboard a ship (i.e. Templated, Assigned, or None)   |
| Tertiary Class     | Short                                | None, [1-9]                                     | United Nations hazardous cargo class used in conjunction with Division.  |
| Tertiary Division  | Short                                | None,1,2,3,4,5,6                                | United Nations hazardous division used in conjunction with Class.  |
| Tertiary IMO Code  | String (uneditable)                  | Any string                                      | The code used to identify the International Maritime Organization Class, Division and Compatibility Group for a particular UN Code.  |
| Time Stamp         | Date                                 | MM/DD/YY 00:00:00                               | Date and Time that a particular record was created.  |
| Total NEW          | Float                                | Precision=6                                     | Net explosive weight in pounds or kilograms.   |

|                 |                                     |   |  |
|-----------------|-------------------------------------|---|--|
| Total Rounds    | Integer                             | Lower Limit=0                                   | A user-defined total number of rounds for a particular cargo item.   |
| Trn Radius      | Integer (editable)                  | Lower Limit=0<br>Upper Limit=9999               | The turning radius required for a vehicle.   |
| Type Cargo      | Character (editable)                | {ABCDEFGHIJKLMNQRSTU<br>VWXYZ0123456789}        | Cargo type code, unique identifier that specifies the hazardous cargo classification.  |
| Type Eqpt       | Character (editable,[1])            | {CDEFGHJKLQIRSTUXY12<br>34567890}               | ECF Model Library type equipment code.   |
| Type Expl       | String (editable)                   | Any string                                      | Type of ammunition, None, Fireworks or Substance.  |
| Type Pack       | String (fixed length[2], editable)  | Any string, 2 char                              | MILSTAMP type pack code.   |
| UIC             | String (editable)                   | Any string                                      | Unit Identification code.  |
| UIC Noun Name   | String                              | Any String                                      | This is a long description for a given UIC.  |
| ULN             | String (fixed length [7], editable) | Any string, 7 char                              | Unit Line Number for a particular cargo item.  |
| UN Code         | Short                               | [UN NA] + UNUM(char 2, fixed int 4)             | A United Nations or North American hazardous identification number.  |
| UN Code List    | String (uneditable)                 | Any string                                      | A series of UN Codes indicating each unique UN Code inside of a multiple hazards cargo item in ICODES. This attribute is not editable and is only used for cargo items with more than one UN Code attached to them.  |
| Unit Of Issue   | String (fixed length [2], editable) | Any string, 2 char                              | Measurement Units used when item was first issued (I.e., feet, inches or pounds)   |
| UPTT Code       | String (fixed length [2], editable) | Any string, 2 char                              | Unit Personnel and Tonnage Table Code  |
| Vessel Stowage  | Character (editable,[1])            | {ABCDE}   | Code specifying the authorized stowage locations for specific cargo.   |
| Volume          | Double                              | Lower Limit=0, Precision=0                      | Volume of the minimum box which encloses the item, in cubic feet or cubic meters.  |
| Voyage Doc #    | String (editable, [4])              | [ABEFGHJKMNPQ][0-9], all caps                   | MILSTAMP voyage document number, an identifier assigned to a ship for a specific voyage.   |
| Weight          | Float                               | Lower Limit=0, Upper Limit=9999999, Precision=0 | Weight of the item, in pounds or kilograms   |
| Width           | Float                               | Lower Limit=0, Upper Limit=9999, Precision=0    | Maximum width of the item, in inches or centimeters.   |
| WPS Record #    | Integer (uneditable)                | Any integer                                     | WPS record number.   |
| WPS Stow Area   | String (uneditable)                 |   | This attribute will be filled in when a network pull is done from WPS to ICODES. The information found here will match the STOW field in WPS for that cargo item. This attribute is provided for use during both the As Loaded process as well as for comparison purposes with the ICODES Stow Area attribute. |
| Zone Identifier | String (uneditable)                 | Any string                                      | Used to indicate what zone a particular cargo item was placed on a ship.   |

## Appendix B: Typical TRANSWAY Planning Scenario

The main TRANSWAY screen (Figure 3.1) is divided into two principal areas. On the left side, moving from the top down, below the main option bar the user will find: three agent icons; objects that may be placed on top of the map (the right side of the screen); a tree-structure that provides quick and convenient access to the data that the system is currently populated with; and, at the bottom a command window for the Tabu agent. On the right side of the screen is a geo-referenced map that allows the user to pan to any part of the world and, subject to the availability of maps, zoom down to street level if desired. Objects representing nodes (e.g., SAAs, APODs, etc.), route segments, impediments, and areas of interest may be moved from the left side of the screen to the right side by simple *click to locate* actions. Alternatively, the user may specify latitude-longitude locations and the selected object will be automatically placed on the map in the correct location. These objects, whether entered by the user or pre-initialized in the system, have attributes that relate to TRANSWAY's internal ontology and provide the necessary context for automated agent actions.



Figure B-1: Main TRANSWAY screen

TRANSWAY is by no means limited to the current set of attributes. With the contractual goal of this first version of a prototype system to demonstrate the typical capabilities of an ontology-based multi-agent system, attributes were selected in a fairly generic fashion based on the feedback that the development team received during early demonstrations, perusal of military documents, and in-house experience with other logistic planning systems such as the Integrated Computerized Deployment System (ICODES) and the Joint Forces Collaborative Toolkit (JFCT).

| Supply Center                    | MOG Parking | MOG Working | Throughput | Short T... | Fixed Wing | Rotary Wing | Vessels | Vehicles |
|----------------------------------|-------------|-------------|------------|------------|------------|-------------|---------|----------|
| Charleston AFB                   | 15          | 10          | 0.0        | 8,289.2    | 15         | 0           | 8       | 0        |
| Dover AFB                        | 15          | 10          | 0.0        | 4,361.3    | 14         | 0           | 0       | 0        |
| Ramstein AFB                     | 15          | 10          | 0.0        | 966.1      | 17         | 0           | 0       | 0        |
| Ash Shuaybah                     | 20          | 10          | 0.0        | 966.1      | 0          | 0           | 0       | 24       |
| Kuwait Intl Airport (KCIA)       | 6           | 5           | 0.0        | 966.1      | 4          | 5           | 0       | 20       |
| Al Taqaddum AB                   | 2           | 2           | 0.0        | 966.1      | 0          | 4           | 0       | 10       |
| Al Udeid AB                      | 2           | 2           | 0.0        | 966.1      | 8          | 5           | 0       | 0        |
| Bagram AB                        | 2           | 2           | 0.0        | 966.1      | 0          | 0           | 0       | 0        |
| Balad Southeast/Camp Anaconda    | 2           | 2           | 0.0        | 966.1      | 1          | 7           | 0       | 16       |
| Kandahar                         | 2           | 2           | 0.0        | 966.1      | 0          | 0           | 0       | 0        |
| Barksdale AFB                    | 15          | 10          | 0.0        | 432.5      | 7          | 0           | 0       | 0        |
| JTF Katrina - Ft Gillem          | 10          | 6           | 0.0        | 432.5      | 7          | 0           | 0       | 0        |
| Kelly/Lackland                   | 10          | 6           | 0.0        | 432.5      | 7          | 0           | 0       | 0        |
| Fort Worth NAS                   | 15          | 6           | 0.0        | 432.5      | 7          | 0           | 0       | 0        |
| Jacksonville NAS                 | 0           | 0           | 0.0        | 57.7       | 0          | 0           | 6       | 0        |
| Dallas-FT Worth IAP              | 15          | 10          | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| England AFB                      | 15          | 10          | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| George Bush IAP                  | 15          | 10          | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Glasgow Prestwick Airport        | 15          | 10          | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| JFK                              | 15          | 10          | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Maxwell AFB                      | 15          | 10          | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Newfoundland Gander Intl Airport | 15          | 10          | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Tyndall AFB                      | 15          | 10          | 0.0        | 0.0        | 0          | 0           | 0       | 20       |
| Mobile Regional AP               | 10          | 6           | 0.0        | 0.0        | 0          | 0           | 0       | 20       |
| NAS Meridian                     | 10          | 6           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Rota NAS                         | 10          | 6           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| William P. Hobby                 | 10          | 6           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Camp Najaf                       | 10          | 5           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Camp Navistar                    | 10          | 5           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Camp Scania (An Numanlyh)        | 10          | 5           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Louis Armstrong IAP              | 0           | 4           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Al Asad AB                       | 5           | 3           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Baton Rouge Metro                | 5           | 3           | 0.0        | 0.0        | 0          | 0           | 0       | 20       |
| Ellington, TX                    | 5           | 3           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Gulf Port IAP                    | 5           | 3           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| JTF FWD - Camp Shelby            | 5           | 3           | 0.0        | 0.0        | 0          | 0           | 0       | 20       |
| Karshi                           | 5           | 3           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Lafayette IAP                    | 5           | 3           | 0.0        | 0.0        | 0          | 0           | 0       | 20       |
| Manas                            | 5           | 3           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Thumrait                         | 5           | 3           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Kessler AFB                      | 0           | 2           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Al Sahra AB/Camp Speicher        | 3           | 2           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Al Qayyarah West                 | 4           | 2           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Herat                            | 4           | 2           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Kirkuk AB                        | 4           | 2           | 0.0        | 0.0        | 0          | 4           | 0       | 0        |
| Mosul AB/Camp Diamondback        | 4           | 2           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Tallil AB/Camp Cedar             | 4           | 2           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Ali Al Salem AB                  | 2           | 1           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Baghdad Intl Airport (BIAP)      | 2           | 1           | 0.0        | 0.0        | 2          | 8           | 0       | 20       |
| Kabul Intl Airport               | 4           | 1           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |
| Ad Diwanayah                     | 0           | 0           | 0.0        | 0.0        | 0          | 0           | 0       | 0        |

Figure B-2: Summary of supplies and available conveyances at supply centers

The report shown in Figure B-2 provides a summary of supplies (short tons) and available conveyances (i.e., fixed wing aircraft, helicopters, ships, and trucks (in convoys)) at most supply centers currently initialized in the system for this particular demonstration scenario. Details of supplies at Charleston and Al Udeid are shown in Figures B-3 and B-4 (in terms of supply Class, number of pallets, number of items per pallet, and short tons), respectively.

| Name  | NSN              | Supply Class | # Pallets | Items/Pallet | Short Tons |
|---|------------------|--------------|-----------|--------------|------------|
| BALLISTIC WINDSHIELD (Group)                      | 2510-01-523-4504 | IX           | 2         | 8            | 34.9       |
| FMTV LOW SIGNATURE ARMORED CAB (LSAC) KIT (Group) | 2510-01-523-0059 | IX           | 206       | 1            | 716.4      |
| FMTV RADIANT ARMORED CAB (RAC) KIT (Group)        | 2540-01-519-0377 | IX           | 558       | 1            | 1,842.8    |
| HEMTT A/C KIT (Group)                             | 4120-01-526-9153 | IX           | 477       | 12           | 943.3      |
| HEMTT ARMOR KIT (Group)                           | 2540-01-520-6821 | IX           | 477       | 1            | 1,086.4    |
| HET A/C KIT (Group)                               | 4120-01-505-4149 | IX           | 2         | 1            | 0.9        |
| HET ARMOR KIT (Group)                             | 2540-01-520-6826 | IX           | 2         | 1            | 6.0        |
| HMMWV AIR CONDITIONERS (Group)                    | 4130-01-523-3966 | IX           | 2         | 8            | 18.7       |
| HMMWV GSIE 2 DOOR KIT (Group)                     | 2510-01-514-9688 | IX           | 2         | 1            | 1.4        |
| HMMWV GSIE 4 DOOR KIT (Group)                     | 2510-01-514-9710 | IX           | 2         | 1            | 2.0        |
| HMMWV O GARA HESS 2 DOOR KIT (Group)              | 2510-01-524-2948 | IX           | 2         | 1            | 2.2        |
| HMMWV O GARA HESS 4 DOOR KIT (Group)              | 2510-01-524-2937 | IX           | 2         | 1            | 2.8        |
| M915A2 CABS (Group)                               | 2540-01-523-1336 | IX           | 2         | 2            | 5.6        |
| M939 ARMOR CABS (Group)                           | 2540-01-522-3749 | IX           | 1009      | 1            | 3,180.9    |
| M998 TROOP CARRIER KITS (Group)                   | 2540-01-525-3585 | IX           | 2         | 2            | 4.6        |
| MEAL READY TO EAT - MRE CASE (Group)              | 8970-00-149-1094 | I            | 100       | 395          | 432.5      |
| PLS A/C KIT (Group)                               | 4120-01-526-9158 | IX           | 2         | 6            | 3.1        |
| PLS ARMOR KIT (Group)                             | 2540-01-520-6819 | IX           | 2         | 1            | 4.8        |

Figure B-3: Details of supplies at Charleston

| Name                                 | NSN              | Supply Class | # Pallets | Items/Pallet | Short Tons |
|--------------------------------------|------------------|--------------|-----------|--------------|------------|
| CARTRIDGE, .50 CAL (Group)           | 1305-00-028-6603 | V            | 140       | 48           | 276.8      |
| CARTRIDGE, 120MM (Group)             | 1315-01-232-4638 | V            | 50        | 30           | 65.1       |
| CARTRIDGE, 5.56MM (Group)            | 1305-01-155-5459 | V            | 180       | 48           | 321.4      |
| MEAL READY TO EAT - MRE CASE (Group) | 8970-00-149-1094 | I            | 70        | 395          | 302.8      |

Figure B-4: Details of supplies at Al Udeid

| First Location                   | Second Location                  | Distance     | Type              |
|----------------------------------|----------------------------------|--------------|-------------------|
| Ash Shuaybah                     | Jacksonville NAS                 | 9,136 n.mi   | Sea Surface Track |
| Ash Shuaybah                     | Charleston AFB                   | 8,943 n.mi   | Sea Surface Track |
| Charleston AFB                   | Rota NAS                         | 3,546.7 n.mi | Air Channel       |
| Dover AFB                        | Ramstein AFB                     | 3,437.7 n.mi | Air Channel       |
| Charleston AFB                   | Glasgow Prestwick Airport        | 3,327.1 n.mi | Air Channel       |
| JFK                              | Ramstein AFB                     | 3,319.7 n.mi | Air Channel       |
| Dover AFB                        | Rota NAS                         | 3,194.1 n.mi | Air Channel       |
| Glasgow Prestwick Airport        | Al Udeid AB                      | 3,024.6 n.mi | Air Channel       |
| Rota NAS                         | Al Udeid AB                      | 3,003.9 n.mi | Air Channel       |
| Dover AFB                        | Glasgow Prestwick Airport        | 2,903.5 n.mi | Air Channel       |
| Ramstein AFB                     | Bagram AB                        | 2,791 n.mi   | Air Channel       |
| Kandahar                         | Ramstein AFB                     | 2,788 n.mi   | Air Channel       |
| Rota NAS                         | Kuwait Intl Airport (KCIA)       | 2,735.1 n.mi | Air Channel       |
| Glasgow Prestwick Airport        | Kuwait Intl Airport (KCIA)       | 2,720.4 n.mi | Air Channel       |
| Manas                            | Ramstein AFB                     | 2,708.9 n.mi | Air Channel       |
| Ramstein AFB                     | Al Udeid AB                      | 2,494.7 n.mi | Air Channel       |
| Rota NAS                         | Balad Southeast/Camp Anaconda    | 2,459.8 n.mi | Air Channel       |
| Newfoundland Gander Intl Airport | Ramstein AFB                     | 2,366.7 n.mi | Air Channel       |
| Ramstein AFB                     | Kuwait Intl Airport (KCIA)       | 2,193.2 n.mi | Air Channel       |
| Ramstein AFB                     | Baghdad Intl Airport (BIAP)      | 1,887.6 n.mi | Air Channel       |
| Balad Southeast/Camp Anaconda    | Ramstein AFB                     | 1,865.4 n.mi | Air Channel       |
| Charleston AFB                   | Newfoundland Gander Intl Airport | 1,490.6 n.mi | Air Channel       |
| Kandahar                         | Manas                            | 805.4 n.mi   | Air Channel       |
| Al Udeid AB                      | Mosul AB/Camp Diamondback        | 791.8 n.mi   | Air Channel       |
| Al Udeid AB                      | Al Qayyarah West                 | 765.9 n.mi   | Air Channel       |
| Al Udeid AB                      | Kirkuk AB                        | 717.8 n.mi   | Air Channel       |
| Charleston AFB                   | Barksdale AFB                    | 687.7 n.mi   | Air Channel       |
| Charleston AFB                   | England AFB                      | 642.1 n.mi   | Air Channel       |
| Al Udeid AB                      | Balad Southeast/Camp Anaconda    | 641.5 n.mi   | Air Channel       |
| Al Udeid AB                      | Al Taqaddum AB                   | 637.2 n.mi   | Air Channel       |
| Al Udeid AB                      | Baghdad Intl Airport (BIAP)      | 613.1 n.mi   | Air Channel       |
| Charleston AFB                   | JFK                              | 553.5 n.mi   | Air Channel       |
| Manas                            | Bagram AB                        | 543.9 n.mi   | Air Channel       |
| Al Udeid AB                      | Thumrait                         | 472 n.mi     | Air Channel       |
| Kirkuk AB                        | Ali Al Salem AB                  | 400.9 n.mi   | Air Channel       |
| Al Asad AB                       | Ali Al Salem AB                  | 371.9 n.mi   | Air Channel       |
| Kelly/Lackland                   | Lafayette IAP                    | 346.4 n.mi   | Air Channel       |
| Charleston AFB                   | Tydall AFB                       | 330.4 n.mi   | Air Channel       |
| Ali Al Salem AB                  | Al Udeid AB                      | 324.6 n.mi   | Air Channel       |
| Maxwell AFB                      | Charleston AFB                   | 323.1 n.mi   | Air Channel       |
| Fort Worth NAS                   | Lafayette IAP                    | 318.9 n.mi   | Air Channel       |
| Dallas-FT Worth IAP              | Lafayette IAP                    | 304.9 n.mi   | Air Channel       |
| Al Udeid AB                      | Kuwait Intl Airport (KCIA)       | 304.4 n.mi   | Air Channel       |
| JTF Katrina - Ft Gillem          | JTF FWD - Camp Shelby            | 285.4 n.mi   | Air Channel       |
| Bagram AB                        | Karshi                           | 283 n.mi     | Air Channel       |
| Kandahar                         | Bagram AB                        | 268.3 n.mi   | Air Channel       |

Figure B-5: Summary report of air channels and sea routes

Figure B-5 provides information about the air channels and sea routes that the system has been initialized with for this particular demonstration scenario. In each case the two end-points and the distance in nautical miles is indicated.

Detailed information about the current compliment of conveyances can be obtained by selecting the appropriate report. Typical examples for various fixed wing aircraft, trucks and ships are shown in

Figures B-6 to B-11, below. The reason that the *speed* and *bearing* attributes in each table are zero is because the conveyances are not currently in-transit.

The screenshot shows the 'Conveyance Viewer' application. On the left, a tree view under 'Conveyances' shows the hierarchy: ConveyanceType > AircraftType > WingedAircraftType > Model: 747. The main 'Report' pane displays a table of 14 Boeing 747 aircraft. All speed and bearing values are 0.0. The location for all aircraft is 32°53'55"N, 80°22'25.8"W. Each row has an 'Edit Unavailabilities' button.

| Name  | Speed | Bearing | Conveyance Type | Pallet Positions | Maximum Cruising Speed | Maximum Range | Location                 | Unavailabilities      |
|-------|-------|---------|-----------------|------------------|------------------------|---------------|--------------------------|-----------------------|
| 747 3 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| 747 5 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| 747 4 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| 747 2 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| 747 1 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| 747 8 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| 747 7 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| 747 4 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| 747 5 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| 747 6 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| 747 3 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| 747 2 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| 747 1 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| 747 4 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| 747 3 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| 747 2 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| 747 1 | 0 mph | 0.0     | 747             | 42               | 435 mph                | 5,719.4 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |

Figure B-6: Boeing 747 aircraft attributes

The screenshot shows the 'Conveyance Viewer' application. On the left, a tree view under 'Conveyances' shows the hierarchy: ConveyanceType > AircraftType > WingedAircraftType > Model: C-5. The main 'Report' pane displays a table of 14 C-5 aircraft. All speed and bearing values are 0.0. The location for all aircraft is 32°53'55"N, 80°22'25.8"W. Each row has an 'Edit Unavailabilities' button.

| Name  | Speed | Bearing | Conveyance Type | Pallet Positions | Maximum Cruising Speed | Maximum Range | Location                 | Unavailabilities      |
|-------|-------|---------|-----------------|------------------|------------------------|---------------|--------------------------|-----------------------|
| C-5 3 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| C-5 5 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| C-5 6 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| C-5 4 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| C-5 2 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| C-5 1 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 32°53'55"N, 80°22'25.8"W | Edit Unavailabilities |
| C-5 3 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| C-5 2 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| C-5 1 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 39°7'45.8"N, 75°27'58"W  | Edit Unavailabilities |
| C-5 5 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| C-5 6 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| C-5 8 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| C-5 7 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| C-5 3 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| C-5 4 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| C-5 2 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |
| C-5 1 | 0 mph | 0.0     | C-5             | 36               | 414.3 mph              | 3,406.3 mi.   | 49°26'12.8"N, 7°36'1.1"E | Edit Unavailabilities |

Figure B-7: C5 aircraft attributes

| Name   | Speed | Bearing | Conveyance Type | Pallet Positions | Maximum Cruising Speed | Maximum Range | Location                   | Unavailabilities                      |
|--------|-------|---------|-----------------|------------------|------------------------|---------------|----------------------------|---------------------------------------|
| C-17 3 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 25°72.3'N, 51°18'54"E      | <a href="#">Edit Unavailabilities</a> |
| C-17 5 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 25°72.3'N, 51°18'54"E      | <a href="#">Edit Unavailabilities</a> |
| C-17 4 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 25°72.3'N, 51°18'54"E      | <a href="#">Edit Unavailabilities</a> |
| C-17 2 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 25°72.3'N, 51°18'54"E      | <a href="#">Edit Unavailabilities</a> |
| C-17 1 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 25°72.3'N, 51°18'54"E      | <a href="#">Edit Unavailabilities</a> |
| C-17 2 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 29°23'5"N, 98°34'13.1"W    | <a href="#">Edit Unavailabilities</a> |
| C-17 1 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 29°23'5"N, 98°34'13.1"W    | <a href="#">Edit Unavailabilities</a> |
| C-17 2 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 32°30'11"N, 93°39'47.3"W   | <a href="#">Edit Unavailabilities</a> |
| C-17 1 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 32°30'11"N, 93°39'47.3"W   | <a href="#">Edit Unavailabilities</a> |
| C-17 2 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 32°46'9"N, 97°26'29"W      | <a href="#">Edit Unavailabilities</a> |
| C-17 1 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 32°46'9"N, 97°26'29"W      | <a href="#">Edit Unavailabilities</a> |
| C-17 2 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 32°53'55"N, 80°22'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| C-17 3 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 32°53'55"N, 80°22'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| C-17 4 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 32°53'55"N, 80°22'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| C-17 1 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 32°53'55"N, 80°22'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| C-17 2 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 33°15'45"N, 44°14'4.6"E    | <a href="#">Edit Unavailabilities</a> |
| C-17 1 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 33°15'45"N, 44°14'4.6"E    | <a href="#">Edit Unavailabilities</a> |
| C-17 2 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 33°37'16"N, 84°21'57"W     | <a href="#">Edit Unavailabilities</a> |
| C-17 1 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 33°37'16"N, 84°21'57"W     | <a href="#">Edit Unavailabilities</a> |
| C-17 3 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 33°56'24.7"N, 44°21'41.1"E | <a href="#">Edit Unavailabilities</a> |
| C-17 2 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 39°745.8"N, 75°27'58"W     | <a href="#">Edit Unavailabilities</a> |
| C-17 1 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 39°745.8"N, 75°27'58"W     | <a href="#">Edit Unavailabilities</a> |
| C-17 5 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 49°26'12.8"N, 7°36'1.1"E   | <a href="#">Edit Unavailabilities</a> |
| C-17 3 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 49°26'12.8"N, 7°36'1.1"E   | <a href="#">Edit Unavailabilities</a> |
| C-17 4 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 49°26'12.8"N, 7°36'1.1"E   | <a href="#">Edit Unavailabilities</a> |
| C-17 2 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 49°26'12.8"N, 7°36'1.1"E   | <a href="#">Edit Unavailabilities</a> |
| C-17 1 | 0 mph | 0.0     | C-17            | 18               | 389 mph                | 2,761.9 mi.   | 49°26'12.8"N, 7°36'1.1"E   | <a href="#">Edit Unavailabilities</a> |

Figure B-8: C17 aircraft attributes

| Name     | Speed | Bearing | Conveyance Type | Pallet Positions | Maximum Cruising Speed | Maximum Range | Location                 | Unavailabilities                      |
|----------|-------|---------|-----------------|------------------|------------------------|---------------|--------------------------|---------------------------------------|
| C-130E 1 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 25°72.3'N, 51°18'54"E    | <a href="#">Edit Unavailabilities</a> |
| C-130E 4 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 29°13'35.8"N, 47°58'8"E  | <a href="#">Edit Unavailabilities</a> |
| C-130E 3 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 29°13'35.8"N, 47°58'8"E  | <a href="#">Edit Unavailabilities</a> |
| C-130E 2 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 29°13'35.8"N, 47°58'8"E  | <a href="#">Edit Unavailabilities</a> |
| C-130E 1 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 29°13'35.8"N, 47°58'8"E  | <a href="#">Edit Unavailabilities</a> |
| C-130E 5 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 29°23'5"N, 98°34'13.1"W  | <a href="#">Edit Unavailabilities</a> |
| C-130E 4 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 29°23'5"N, 98°34'13.1"W  | <a href="#">Edit Unavailabilities</a> |
| C-130E 3 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 29°23'5"N, 98°34'13.1"W  | <a href="#">Edit Unavailabilities</a> |
| C-130E 2 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 29°23'5"N, 98°34'13.1"W  | <a href="#">Edit Unavailabilities</a> |
| C-130E 1 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 29°23'5"N, 98°34'13.1"W  | <a href="#">Edit Unavailabilities</a> |
| C-130E 4 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°30'11"N, 93°39'47.3"W | <a href="#">Edit Unavailabilities</a> |
| C-130E 5 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°30'11"N, 93°39'47.3"W | <a href="#">Edit Unavailabilities</a> |
| C-130E 3 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°30'11"N, 93°39'47.3"W | <a href="#">Edit Unavailabilities</a> |
| C-130E 2 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°30'11"N, 93°39'47.3"W | <a href="#">Edit Unavailabilities</a> |
| C-130E 1 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°30'11"N, 93°39'47.3"W | <a href="#">Edit Unavailabilities</a> |
| C-130E 4 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°46'9"N, 97°26'29"W    | <a href="#">Edit Unavailabilities</a> |
| C-130E 5 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°46'9"N, 97°26'29"W    | <a href="#">Edit Unavailabilities</a> |
| C-130E 3 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°46'9"N, 97°26'29"W    | <a href="#">Edit Unavailabilities</a> |
| C-130E 2 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°46'9"N, 97°26'29"W    | <a href="#">Edit Unavailabilities</a> |
| C-130E 1 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 32°46'9"N, 97°26'29"W    | <a href="#">Edit Unavailabilities</a> |
| C-130E 5 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 33°37'16"N, 84°21'57"W   | <a href="#">Edit Unavailabilities</a> |
| C-130E 3 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 33°37'16"N, 84°21'57"W   | <a href="#">Edit Unavailabilities</a> |
| C-130E 4 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 33°37'16"N, 84°21'57"W   | <a href="#">Edit Unavailabilities</a> |
| C-130E 2 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 33°37'16"N, 84°21'57"W   | <a href="#">Edit Unavailabilities</a> |
| C-130E 1 | 0 mph | 0.0     | C-130E          | 6                | 344.1 mph              | 1,150.8 mi.   | 33°37'16"N, 84°21'57"W   | <a href="#">Edit Unavailabilities</a> |

Figure B-9: C130 aircraft attributes

Conveyance Viewer

Conveyances

ConveyanceType

AircraftType

WingedAircraftType

Model : 747

Model : B-747-400F

Model : C-5

Model : C-17

Model : C-130E

Model : C-130H

Model : C-130J

Model : L-1011-200F

Model : MD-11F

RotaryAircraftType

VehicleType

TruckType

Model : 20-Ft Flatbed Truck

VesselType

Model : Vessel

Report

| Name                   | Speed | Bearing | Conveyance Type     | Pallet Positions | Maximum Cruising Speed | Maximum Range | Location                 | Unavailabilities      |
|------------------------|-------|---------|---------------------|------------------|------------------------|---------------|--------------------------|-----------------------|
| 20-Ft Flatbed Truck 2  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 4  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 3  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 8  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 7  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 6  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 5  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 13 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 18 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 17 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 16 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 15 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 14 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 12 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 11 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 10 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 9  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 20 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 19 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 1  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°13'35.8"N, 47°58'8"E  | Edit Unavailabilities |
| 20-Ft Flatbed Truck 2  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 4  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 3  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 9  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 10 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 8  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 7  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 6  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 5  | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 13 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 17 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 21 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 24 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 23 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |
| 20-Ft Flatbed Truck 22 | 0 mph | 0.0     | 20-Ft Flatbed Truck | 3                | 40.3 mph               | 400.5 mi.     | 29°2'45.2"N, 48°9'15.1"E | Edit Unavailabilities |

Figure B-10: Truck convoy attributes

The screenshot displays the 'Conveyance Viewer' application. On the left, a tree view under 'Conveyances' shows a hierarchy: 'ConveyanceType' (expanded) contains 'AircraftType' (expanded), which includes 'WingedAircraftType' (expanded). Under 'WingedAircraftType', there are several 'Model' entries: '747', 'B-747-400F', 'C-5', 'C-17', 'C-130E', 'C-130H', 'C-130J', 'C-130J-30', 'L-1011-200F', 'MD-11F', 'RotaryAircraftType', 'VehicleType' (expanded), 'TruckType' (expanded), and 'VesselType' (expanded). Under 'VesselType', there is a 'Model : Vessel' entry, which is currently selected.

The main area on the right, titled 'Report', displays a table of vessel data. The table has the following columns: Name, Speed, Bearing, Conveyance Type, Pallet Positions, Maximum Cruising Speed, Maximum Range, Location, and Unavailabilities. The data rows list various vessels (Vessel 1 through Vessel 8) with their respective attributes. Each 'Unavailabilities' cell contains an 'Edit Unavailabilities' button.

| Name     | Speed | Bearing | Conveyance Type | Pallet Positions | Maximum Cruising Speed | Maximum Range | Location                  | Unavailabilities                      |
|----------|-------|---------|-----------------|------------------|------------------------|---------------|---------------------------|---------------------------------------|
| Vessel 2 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 30°14'8.9"N, 81°40'49.8"W | <a href="#">Edit Unavailabilities</a> |
| Vessel 3 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 30°14'8.9"N, 81°40'49.8"W | <a href="#">Edit Unavailabilities</a> |
| Vessel 6 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 30°14'8.9"N, 81°40'49.8"W | <a href="#">Edit Unavailabilities</a> |
| Vessel 5 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 30°14'8.9"N, 81°40'49.8"W | <a href="#">Edit Unavailabilities</a> |
| Vessel 4 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 30°14'8.9"N, 81°40'49.8"W | <a href="#">Edit Unavailabilities</a> |
| Vessel 1 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 30°14'8.9"N, 81°40'49.8"W | <a href="#">Edit Unavailabilities</a> |
| Vessel 3 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 32°53'55"N, 80°2'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| Vessel 5 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 32°53'55"N, 80°2'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| Vessel 7 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 32°53'55"N, 80°2'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| Vessel 8 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 32°53'55"N, 80°2'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| Vessel 6 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 32°53'55"N, 80°2'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| Vessel 4 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 32°53'55"N, 80°2'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| Vessel 2 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 32°53'55"N, 80°2'25.8"W   | <a href="#">Edit Unavailabilities</a> |
| Vessel 1 | 0 mph | 0.0     | Vessel          | 1000             | 17.3 mph               | 23,015.6 mi.  | 32°53'55"N, 80°2'25.8"W   | <a href="#">Edit Unavailabilities</a> |

Figure B-11: Typical ship attributes

A typical request for *add on armor* is shown in Figure B-12. It requires deliver to Al Udeid, with a *high* priority and an earliest and latest time for delivery window of 25 to 31 December 2005.

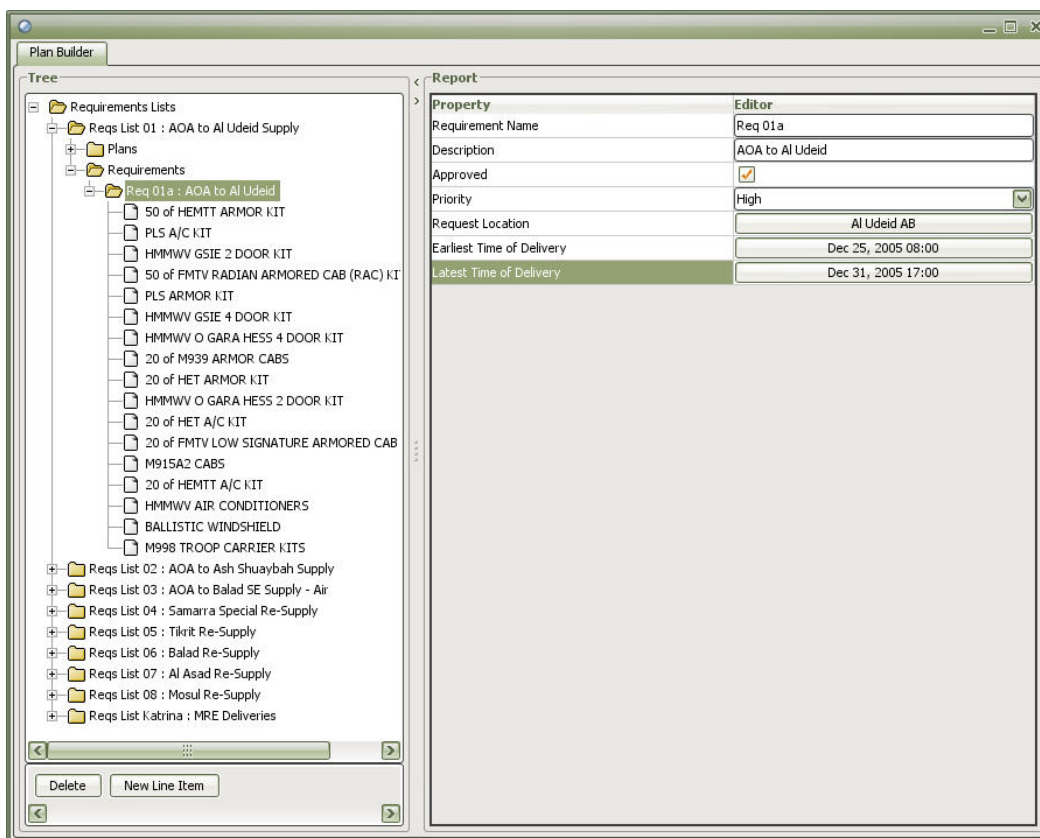


Figure B-12: Add-on-Armor (AOR) request for delivery to Al Udeid

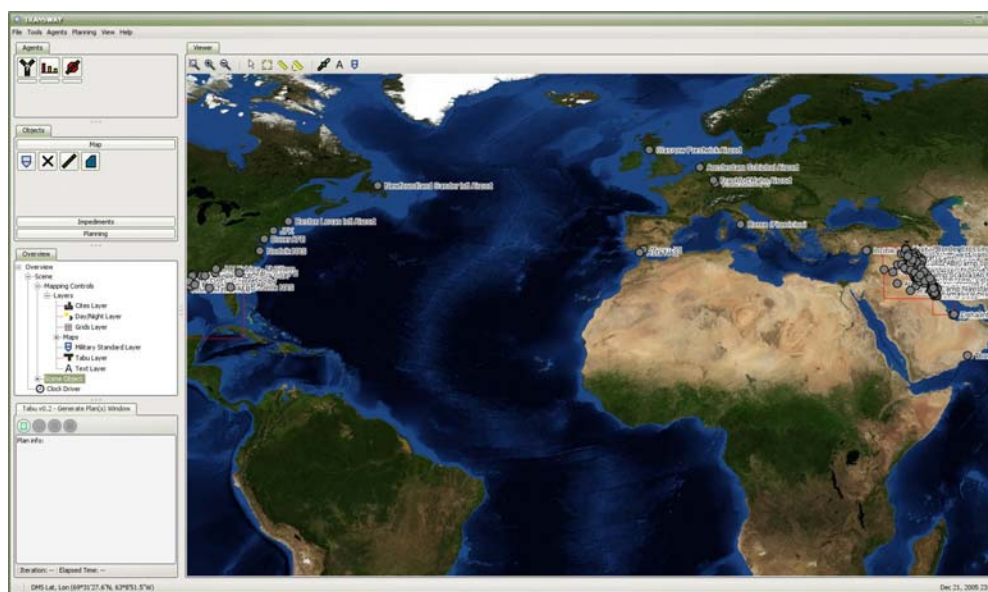


Figure B-13: User zooms in on map to reduce clutter

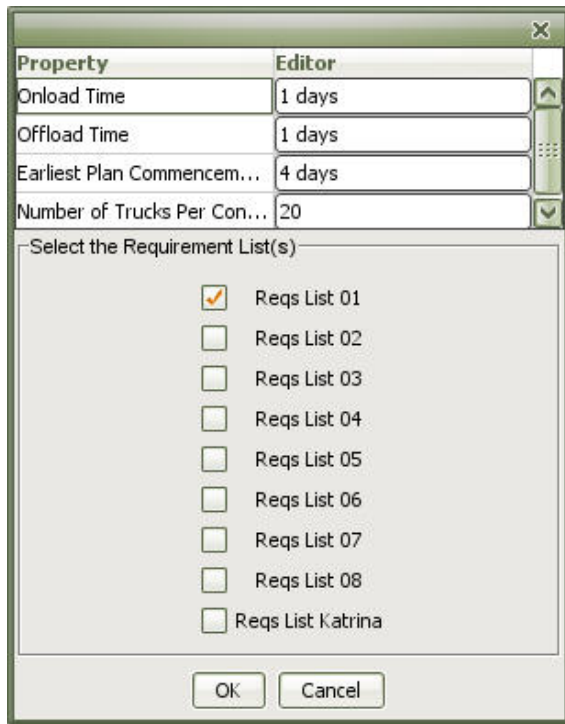


Figure B-14: Tabu agent interface



Figure B-15: Control of search duration

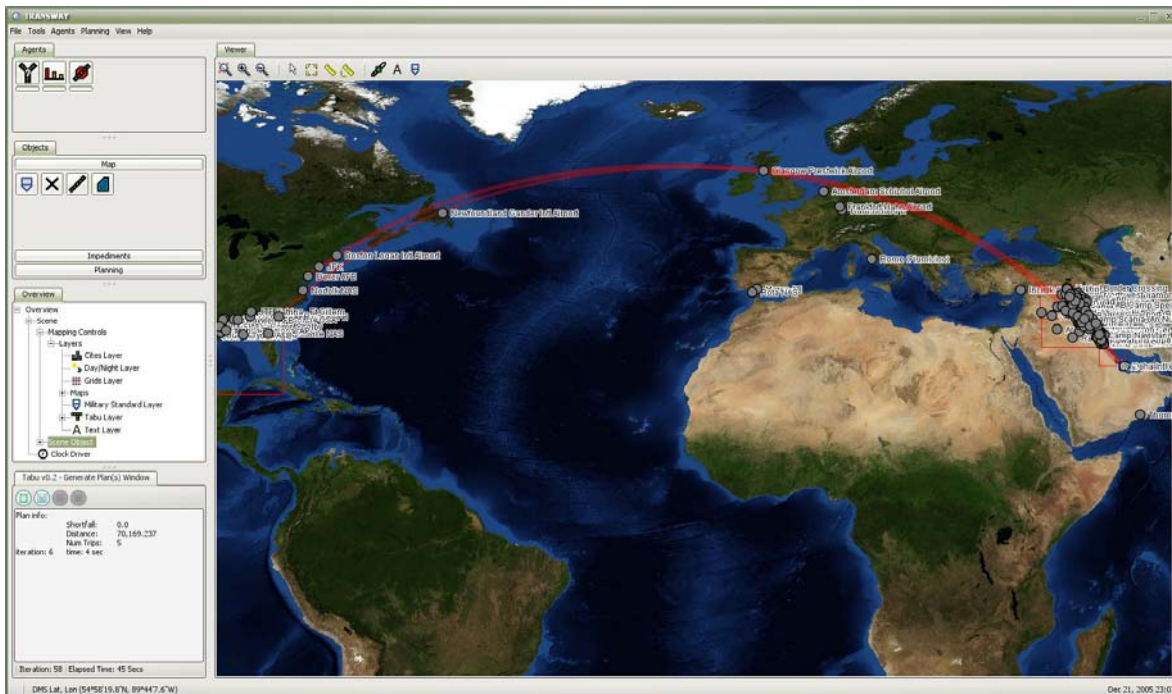


Figure B-16: Completed first plan showing routes

To fulfill the request for the shipment of *add-on-armor* to Al Udeid (Figure B-12) the user activates the Tabu agent and selects the appropriate *requirement* from the displayed Requirement Lists (Figure B-14). In this case the Al Udeid *requirement* is Requirement List 1. Since the Tabu agent has the ability to continue its search for an optimum delivery plan even after it has found a way of satisfying the

*requirement*, the user has the option of either setting a maximum time for the planning activity (Figure B-15) or allowing the agent to continue until all alternatives have been explored. Of course it is not

| Property              | Editor             |
|-----------------------|--------------------|
| Name                  | Weather Impediment |
| Start Time            | Dec 21, 2005 23:03 |
| End Time              | Dec 21, 2006 23:03 |
| Graphics              | ▼                  |
| Weather Effects       | ▲                  |
| Speed                 | 0 knots            |
| Bearing               | 0.0                |
| Wind Velocity         | 0 knots            |
| Wind Gusts            | 0 knots            |
| Wind Peak             | 0 knots            |
| Prevailing Visibility | 0 n.mi             |
| Surface Visibility    | 0 n.mi             |
| Tower Visibility      | 0 n.mi             |
| Cloud Cover           | 0.0                |
| Sky Ceiling           | 0 n.mi             |
| Altimeter             | 0.0                |
| Sea Level             | 0.0                |
| Precipitation         | Heavy ▼            |
| Obstructions          | None ▼             |
| Temperature           | 0.0                |
| Dew Point             | 0.0                |

Figure B-17: Weather Impediment

expected that the user would ever want to wait for that length of time and therefore the option for the user to simply stop the agent is available. In future versions of TRANSWAY, particularly if the Tabu agent were to be implemented in an opportunistic mode (i.e., in a manner that would activate the planning process without user involvement as soon as the conditions on which an existing plan were originally based have changed), it would be a relatively simple matter to restrict the extensiveness of the search for an optimum plan. For example, the search could be automatically aborted if after either a specified period of time or a given number of generated plans no better plan has been found.

| Priority | Alerts  | Acknowled...             |
|----------|---|--------------------------|
| High     | Plan: 1 is no longer valid because: Dover AFB to Glasgow Prestwick Airport has changed! | <input type="checkbox"/> |

Plan: 1 is no longer valid because:  
Dover AFB to Glasgow Prestwick Airport has changed!

| Property        | Editor   |
|-----------------|--|
| Description     | Plan: 1 is no longer valid because: Dover AFB to Glasgow |
| Priority        | High ▼   |
| Acknowledged    | <input type="checkbox"/>                                 |
| Recommendations | View Recommendations                                     |

Acknowledge All Unacknowledge All View All View Unacknowledged View Acknowledged

Figure B-18: Impediment agent alert

For the completed plan the route is shown in Figure B-16 by means of a red line. Next the user enters an impediment in the form of an adverse weather report that essentially eliminates Glasgow as a refueling stop (Figure B-17). Immediately, the Impediment agent alerts the user and suggests that re-planning is in order (Figure B-18). Again, also in the case of impediments, this first version of TRANSWAY provides only one type of generic impediment (i.e., a weather condition), with the objective of demonstrating the

kinds of causes that would require re-planning that could be easily implemented in subsequent versions of the system, based on user preferences and priorities.

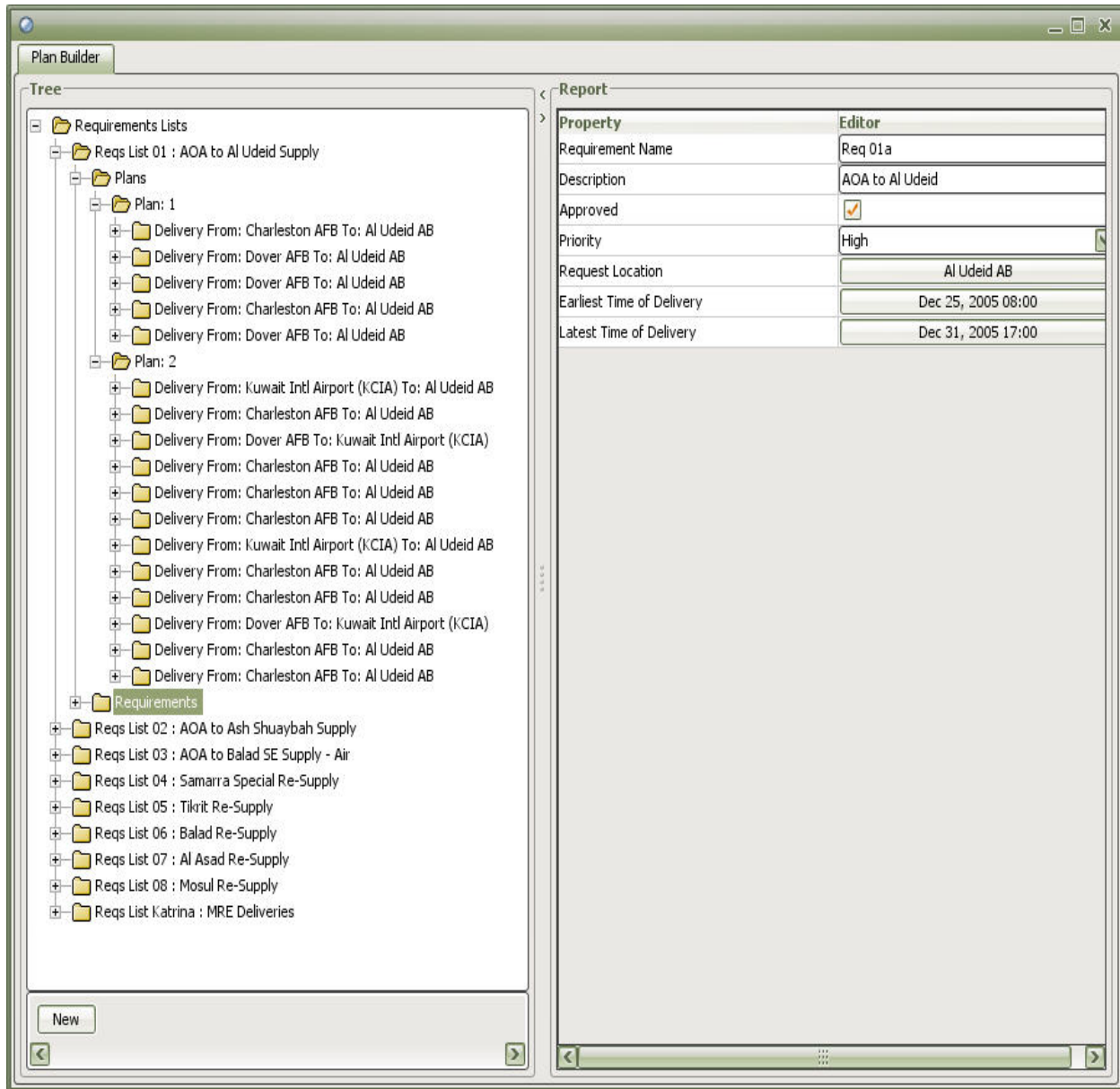


Figure B-19: Summary of deliveries for the first and second plans

To initiate a re-planning action the user proceeds in the same manner as described previously for the generation of the first plan (Figures B-14 to B-16). The user will notice that during the generation of each plan the routes that are being explored by the Tabu agent are dynamically indicated on the map display. Temporarily displayed green lines indicate drop-off points that are being considered. Red lines indicate actual delivery routes with the thickness of the red line providing a proportional indication of the volume of supplies being transported along that particular route. Summary lists of the deliveries involved in both plans are shown in Figure B-19.

Even though this first test-bed version of TRANSWAY is purposely limited in scope it does allow the user to explore the details of each delivery plan (i.e., start and end locations, conveyances and routes used, start and end times, and duration of each trip), as shown in Figures B-20 to B-23.

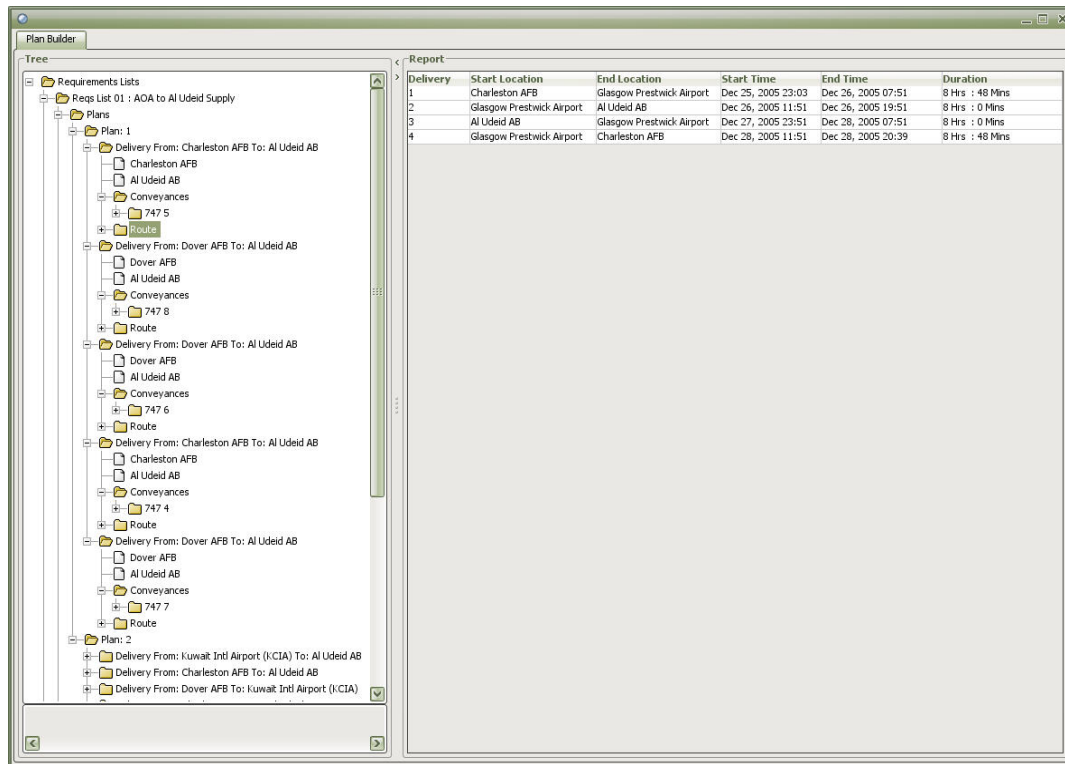


Figure B-20: Typical drill-down details of the first plan

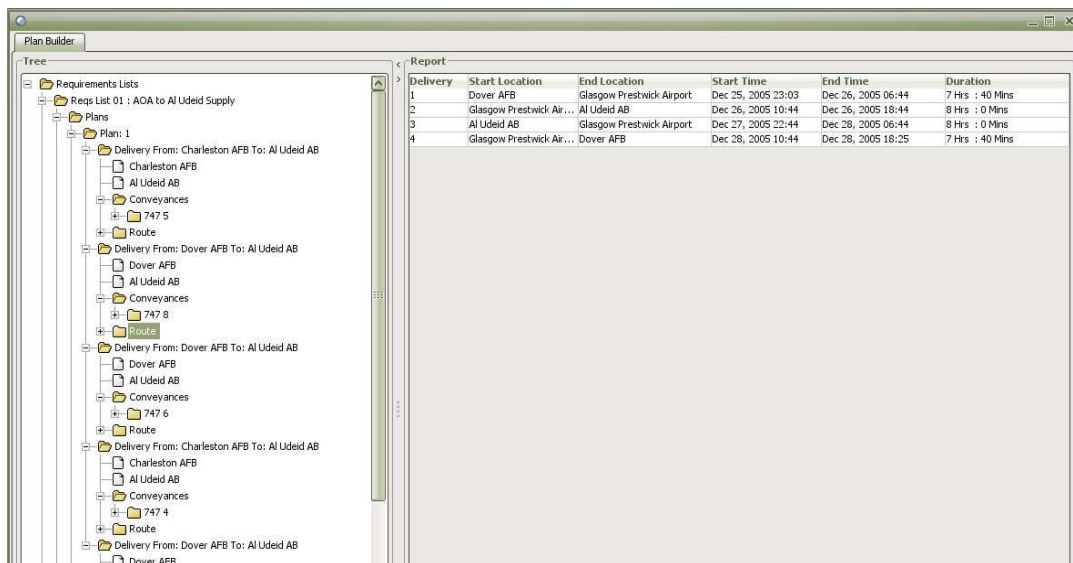


Figure B-21: Typical drill-down details of the first plan

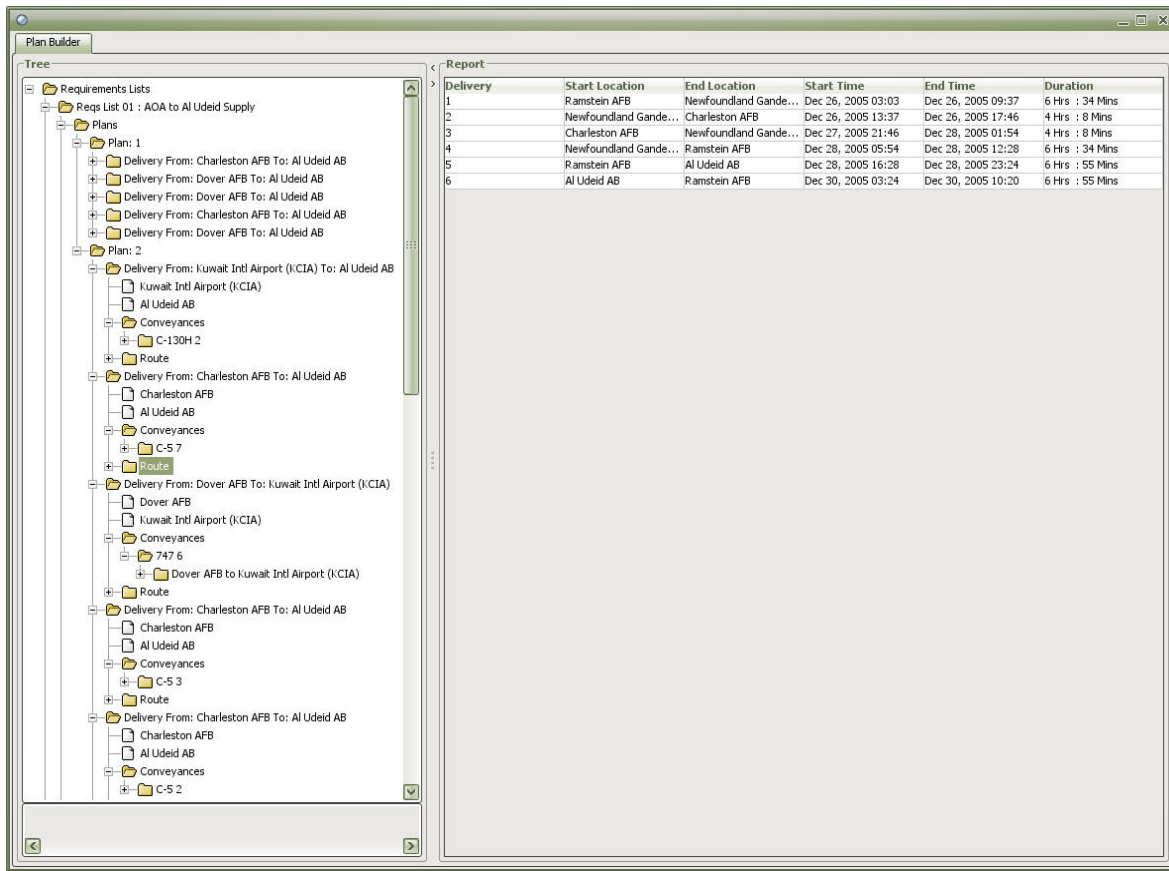


Figure B-22: Typical drill-down details of the second plan

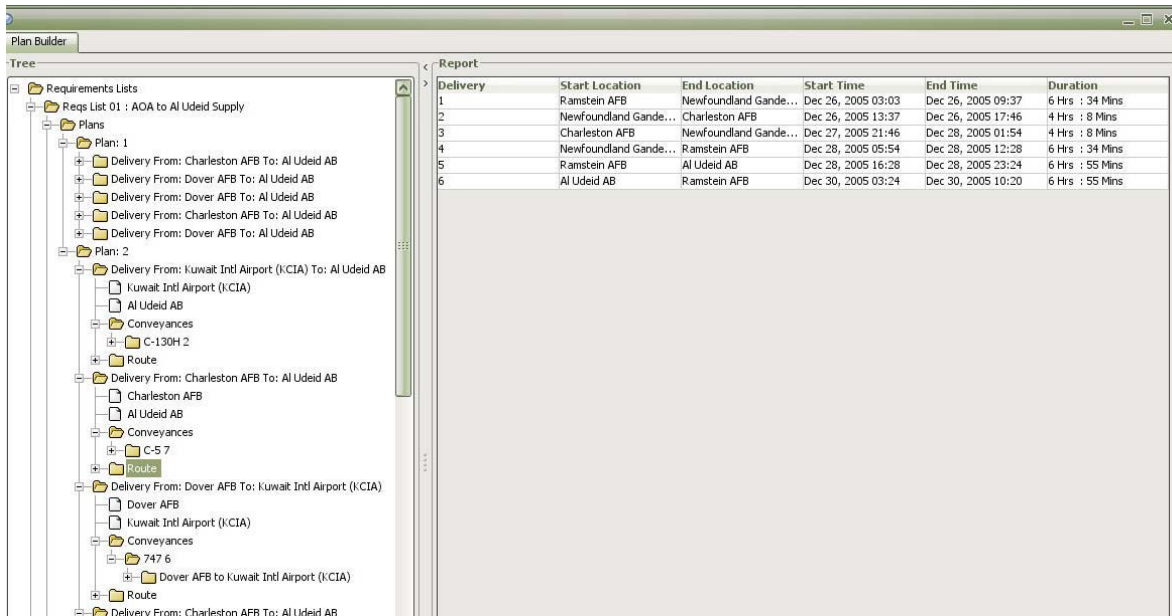


Figure B-23: Typical drill-down details of the second plan

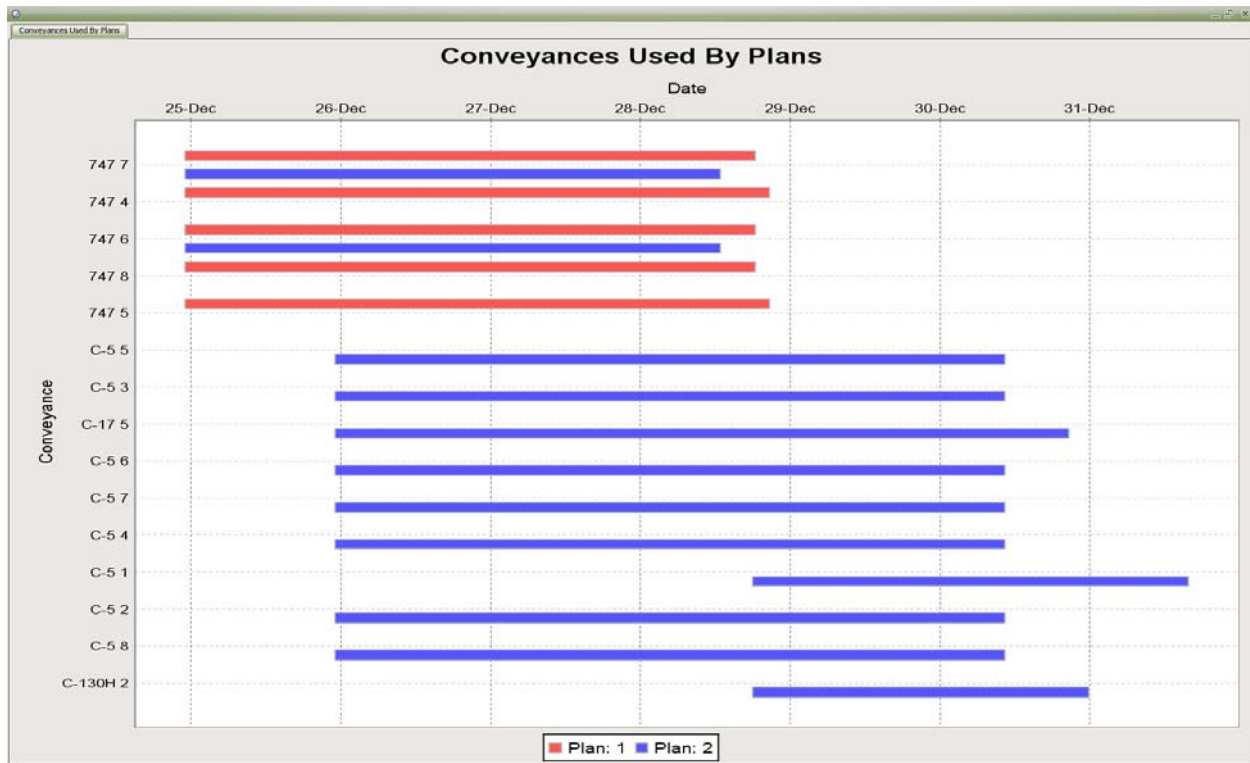


Figure B-24: Comparison of conveyances needed in support of the first and second plans

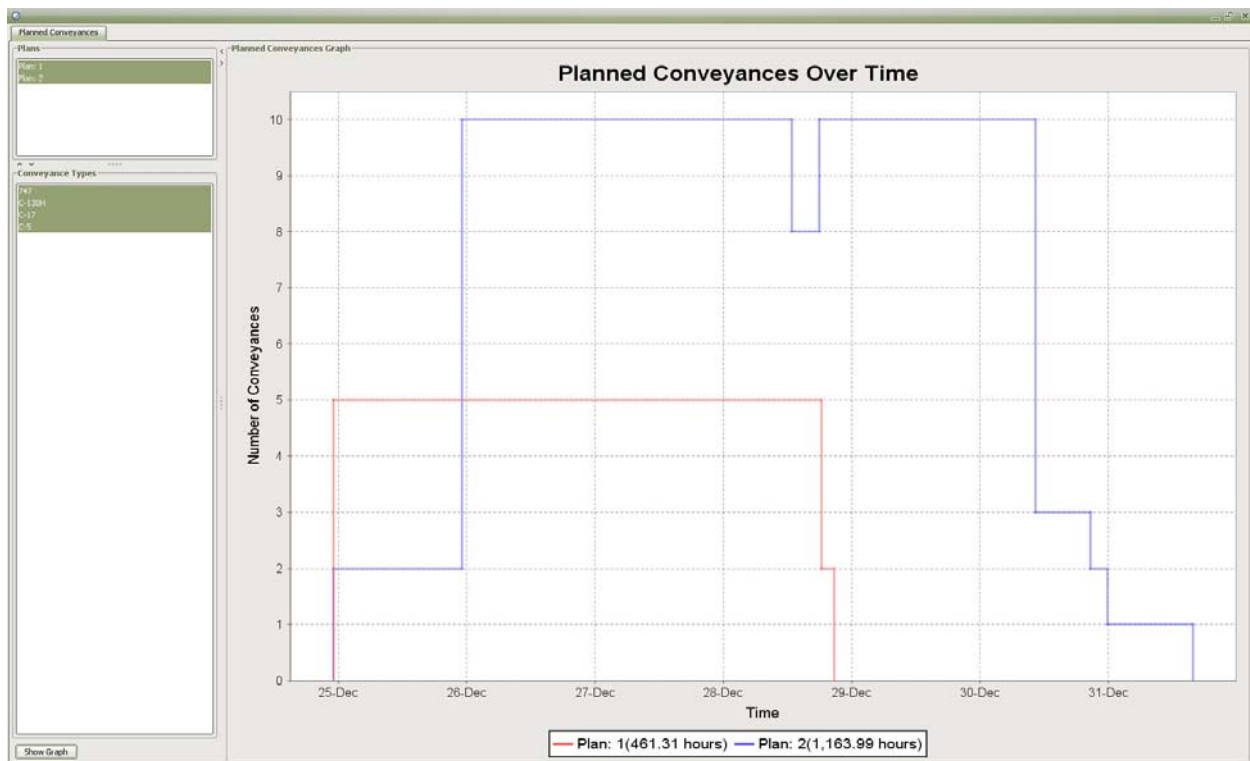


Figure B-25: Comparison of overall lift requirements for the first and second plans

Apart from the ability of the user to drill down into the details of each delivery plan there are a number of comparative graphical reports available, such as the utilization of specific conveyances by each plan shown in Figure B-24 and the number of conveyances that are required to support each plan over time shown in Figure B-25.

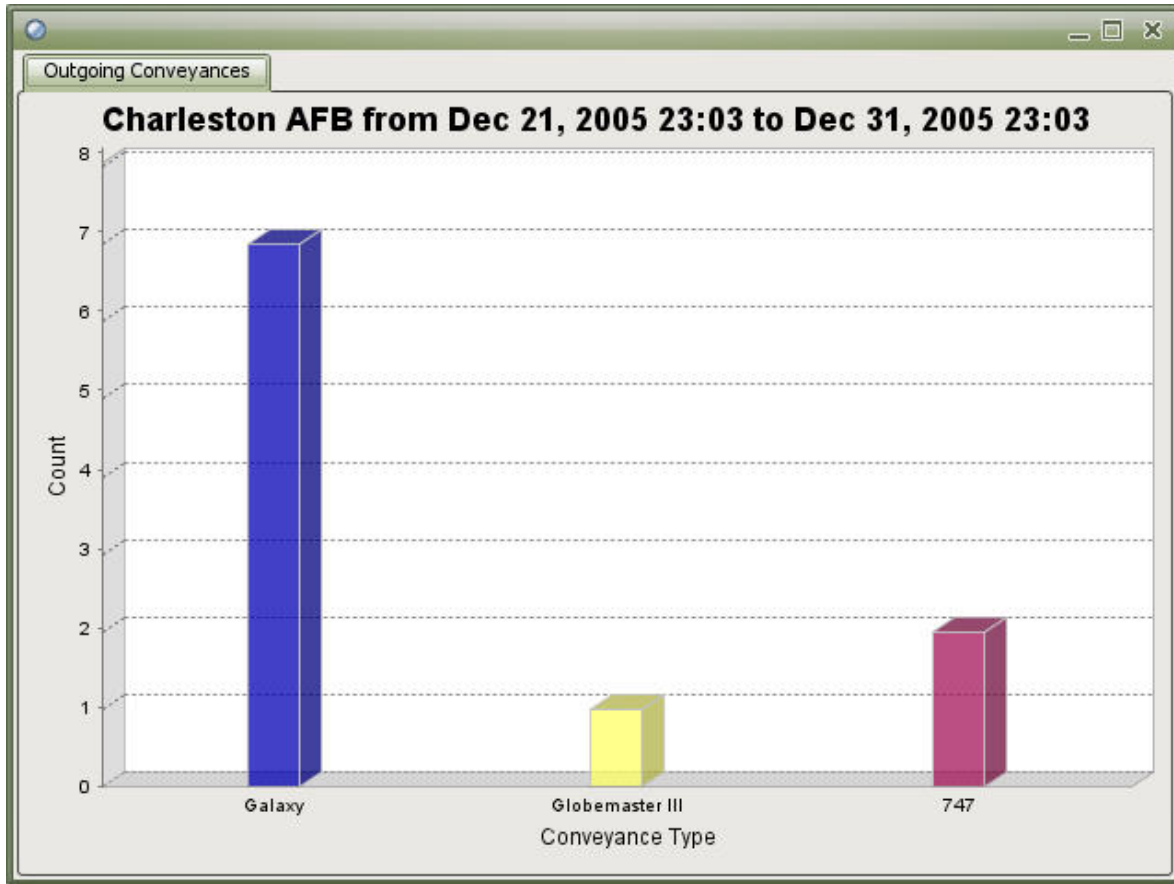


Figure B-26: Departures from Charleston by conveyance type

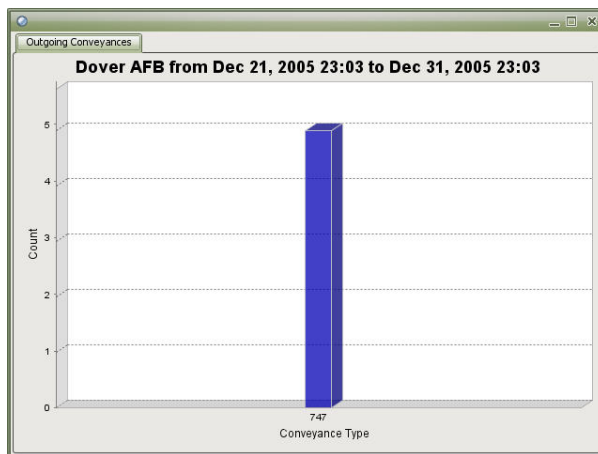


Figure B-27: Departures from Dover

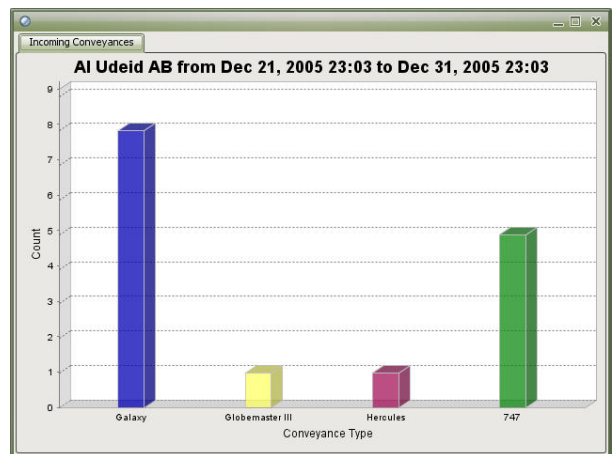


Figure B-28: Departures from Al Udeid

Figures B-26 to B-28 show examples of conveyance departures from the Charleston, Dover and Al Udeid APODs, respectively. Similar reports are available for cargo transfers by date (Figures B-29 to B-

30) in terms of what was lifted yesterday, the current inventory, and what is planned to be lifted during the next 72 hours. In this way the user is able to determine the expected volume of shipments from any particular APOD on a daily basis. The dates selected for the example bar chart reports shown in Figures B-29 and B-30 are December 23 to 26, 2005.

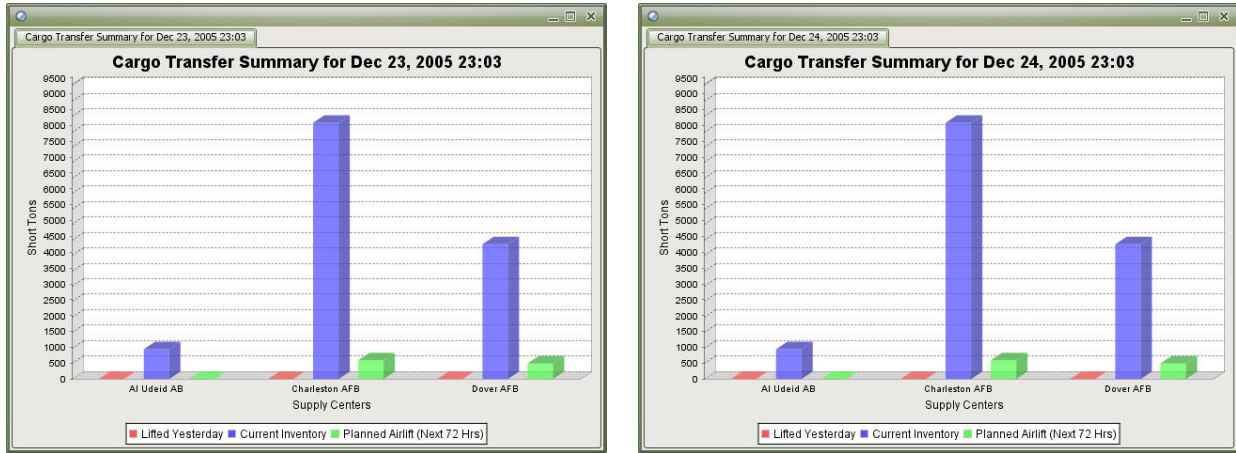


Figure B-29: Typical cargo transfer history, status, and 72-hour projections

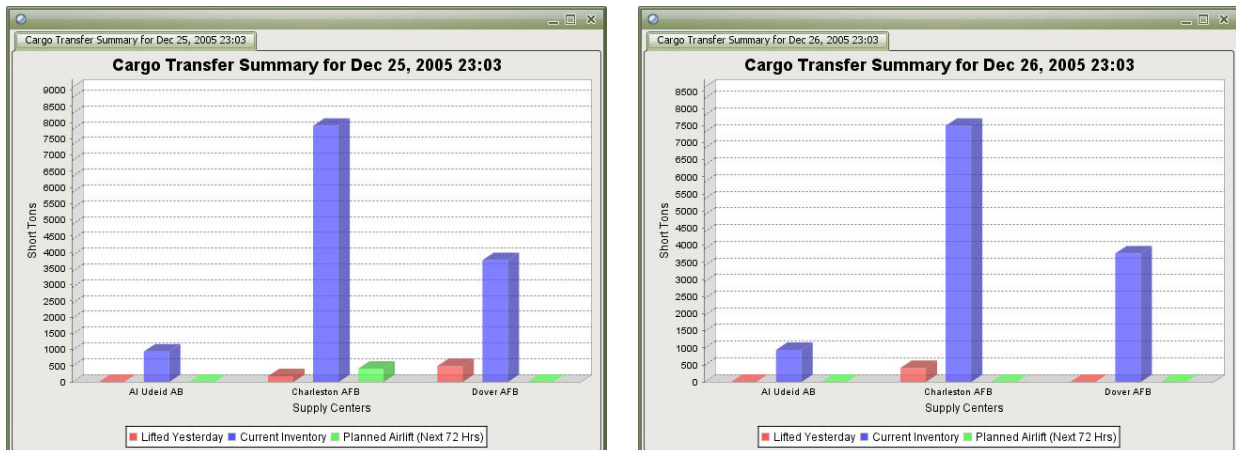


Figure B-30: Typical cargo transfer history, status, and 72-hour projections

Again, these reports are intended to be examples of the kind of information that can be made available by TRANSWAY. The development team will be guided by feedback from users in future development cycles. The reporting capabilities of the system can be easily extended in any direction within the constraints of data availability.

## Appendix C: TRANSWAY Data Dictionary

| TRANSWAY Name                        | Type        | Data Domain   | TRANSWAY Description   |
|--------------------------------------|-------------|---|--|
| <b><u>Person/<br/>Passenger:</u></b> |             |   |  |
| SSN                                  | string      | Any string  | Social security number of person who is required to be loaded onto a conveyance as a passenger.                      |
| lastName                             | string      | Any string  | Last name of passenger.  |
| firstName                            | string      | Any string  | First name of passenger.   |
| middleName                           | string      | Any string  | Middle name of passenger.  |
| dateOfBirth                          | integer     | numeric   | Date of birth of passenger.  |
| bloodType                            | enumeration | APOS, BPOS, ABPOS, and OPOS                                   | Blood type of passenger.   |
| gender                               | enumeration | male, female, unknown   | The adjusted height of the parent for a particular association as a result of taking the dimensions of the children. |
| height                               | float       | numeric   | Height of passenger in inches (in).  |
| weight                               | float       | numeric   | Weight of passenger in pounds (lb).  |
| <b><u>Alerts:</u></b>                |             |   |  |
| type                                 | enumeration | General, supply shortfall, conveyance shortfall, plan invalid | Type of alert provided by an agent.  |
| priority                             | enumeration | Low, medium, high   | Priority of the alert generated by an agent.   |
| summaryMessage                       | string      | Any string  | Explanatory message generated by agent in conjunction with an alert.   |
| acknowledged                         | boolean     | Acknowledgement (true/false)                                  | Status of acknowledgement of agent alert by user.  |
| <b><u>Node:</u></b>                  |             |   |  |
| type                                 | enumeration | SSA, POD, APOD, SPOD, POE, APOE, SPOE                         | Node type.   |

|                                     |             |  |   |
|-------------------------------------|-------------|--|---|
| earliestAllowableTransportDeparture | integer     | numeric  | Earliest time at which conveyance is able or authorized to depart.  |
| latestAllowableTransportDeparture   | integer     | numeric  | Latest time at which conveyance is able to depart to meet future deadlines.   |
| MOGw                                | integer     | numeric  | Maximum on ground – working (maximum number of aircraft that can be loaded or unloaded at a particular APOD/E at any one time). |
| MOGp                                | integer     | numeric  | Maximum on ground – parking (maximum number of aircraft that can be parked at a particular APOD/E at any one time).             |
| throughput                          | float       | numeric  | Quantity of cargo that can be moved out of the node in pounds per hour (lb/hr).   |
| fuelQuantity                        | float       | numeric  | Amount of fuel holding capacity.  |
| holdingCapacity                     | float       | numeric  | Amount of cargo that can be stored at node.   |
| <b><u>Route:</u></b>                |             |  |   |
| routeType                           | enumeration | paved road, unpaved road, air channel, water channel | Type of air or surface route.   |
| length                              | float       | numeric  | Length of route (or route leg) in nautical miles (nm).  |
| locationA                           | float       | Struct   | Location of start node of route in terms of latitude/longitude/altitude.  |
| locationB                           | float       | Struct   | Location of end node of route in terms of latitude/longitude/altitude.  |
| <b><u>Impediment:</u></b>           |             |  |   |
| type                                | enumeration | unknown, weather, attack, explosion                  | Type of impediment (however, only the weather impediment is implemented in Version 1.0).  |
| degree                              | enumeration | Low, medium, high                                    | Overall severity of impediment.   |
| precipitation                       | enumeration | none, hail, snow                                     | Type of precipitation impediment.   |
| obstructions                        | enumeration | None, light, moderate, heavy                         | Degree of obstruction due to impediment.  |
| duration                            | float       | numeric  | Time period during which the impediment is in effect in hours (hr).   |
| speed                               | float       | numeric  | Speed at which weather front is moving in nautical miles (nm).  |

|                           |             |                                     |   |
|---------------------------|-------------|-------------------------------------|---|
| bearing                   | float       | numeric                             | Direction in which weather front is moving.                             |
| <b><u>Conveyance:</u></b> |             |                                     |   |
| position                  | float       | Struct                              | Position of conveyance in terms of latitude/longitude/altitude.         |
| speed                     | float       | numeric                             | Current speed of conveyance in knots (kph).                             |
| range                     | float       | numeric                             | Total distance conveyance can travel regardless of refueling need.      |
| homeLocation              | float       | Struct                              | Conveyance home base in terms of latitude/longitude/altitude.           |
| loadTime                  | float       | numeric                             | Standard time to load conveyance.                                       |
| unloadTime                | float       | numeric                             | Standard time to unload conveyance.                                     |
| maxWeighthCapacity        | float       | numeric                             | Maximum weight conveyance can operate with.                             |
| maxPalletCapacity         | float       | numeric                             | Maximum number of pallets that can be loaded onto conveyance.           |
| type                      | enumeration | truck, vessel, rotary, winged, rail | Type of conveyance (however, rail is not implemented in Version 1.0).   |
| inflightRefuel            | boolean     | capable (true/false)                | Whether aircraft conveyance can be refueled in flight.                  |
| length                    | float       | numeric                             | Maximum standard length of conveyance in inches (in).                   |
| width                     | float       | numeric                             | Maximum standard width of conveyance in inches (in).                    |
| height.                   | float       | numeric                             | Maximum standard height of conveyance in inches (in).                   |
| weight                    | float       | numeric                             | Maximum standard weight of unloaded conveyance.                         |
| fuelConsumption           | float       | numeric                             | Fuel consumption of conveyance at cruising speed.                       |
| location                  | float       | Struct                              | Current location of conveyance in terms of latitude/longitude/altitude. |
| maxContainer              | integer     | numeric                             | Maximum number of containers that can be loaded onto conveyance.        |

|   |             |                                      |   |
|---|-------------|--------------------------------------|---|
| militaryCivilian                                | enumeration | military, civilian                   | Whether conveyance has military or civilian ownership.                                      |
| crewSize  | integer     | numeric                              | Number of persons needed to operate conveyance.   |
| unrefueledRange                                 | float       | numeric                              | Maximum standard distance conveyance can travel without refueling.                          |
| <b><u>Cargo:</u></b>                            |             |                                      |   |
| supplyClass                                     | enumeration | I, II, III, IV, V, VI, VII, VIII, IX | Supply Class (however, only Classes I, V, and IX (partial) are implemented in Version 1.0). |
| unitMeasure                                     | enumeration | Each, box, case                      | Packaging configuration of the cargo item.  |
| packageQuantity                                 | integer     | numeric                              | Number of items per package.  |
| length  | float       | numeric                              | Maximum length of package in inches (in).   |
| width   | float       | numeric                              | Maximum width of package in inches (in).  |
| height  | float       | numeric                              | Maximum height of package in inches (in).   |
| weight  | float       | numeric                              | Maximum weight of package in pounds (lb).   |
| NSN   | string      | Any string (13 characters)           | National Stock Number.  |
| commodityCode                                   | string      | Any string                           | Commodity code of cargo item.   |
| <b><u>Requirement/Request for Supplies:</u></b> |             |                                      |   |
| cargoList                                       | (n/a)       | (n/a)                                | List of requested types of supply items.  |
| quantity  | integer     | numeric                              | Quantity of each type of supply item requested.   |
| locationDestination                             | float       | Struct                               | Location of delivery destination in terms of latitude/longitude/altitude.                   |
| ETA   | integer     | numeric                              | Earliest Time of Arrival at delivery destination.   |
| LTA   | integer     | numeric                              | Latest Time of Arrival at delivery destination.   |

|                          |             |                                   |  |
|--------------------------|-------------|-----------------------------------|--|
| priority                 | enumeration | Low, medium, high                 | Priority assigned to request for supplies.   |
| <b><u>Pallet:</u></b>    |             |                                   |  |
| location                 | float       | Struct                            | Current location of pallet in terms of latitude/longitude/altitude.                |
| type                     | enumeration | 463L, standard wood, factory wood | Type of pallet (however, only the 463L pallet type is implemented in Version 1.0). |
| quantity                 | integer     | numeric                           | Quantity of this type of pallet available at the location.                         |
| totalWeight              | float       | numeric                           | Holding capacity of pallet in pounds (lb).   |
| totalHeight              | float       | numeric                           | Maximum allowable height of pallet and contents in inches (in).                    |
| palletCondition          | enumeration | serviceable, unusable, repairable | Condition of pallet.   |
| length                   | float       | numeric                           | Maximum length of pallet in inches (in).   |
| width                    | float       | numeric                           | Maximum width of pallet in inches (in).  |
| height                   | float       | numeric                           | Maximum height of empty pallet in inches (in).                                     |
| weight                   | float       | numeric                           | Maximum weight of empty pallet in pounds (lb).                                     |
| weightNetting            | float       | numeric                           | Maximum weight of netting and tie downs in pounds (lb).                            |
| volume                   | float       | numeric                           | Maximum volume of pallet and contents in cubic feet (cf).                          |
| stackingHeight           | integer     | numeric                           | Maximum number of pallets that can be stacked.                                     |
| numberContainer          | integer     | numeric                           | Maximum number of pallets allowed in a container.                                  |
| <b><u>Container:</u></b> |             |                                   |  |
| location                 | float       | Struct                            | Current location of container in terms of latitude/longitude/altitude.             |
| type                     | enumeration | Standard, dry, rack, reefer       | Type of container.   |

|                    |             |                                    |   |
|--------------------|-------------|------------------------------------|---|
| quantity           | integer     | numeric                            | Quantity of this type of container available at the location. |
| totalWeight        | float       | numeric                            | Holding capacity of container in pounds (lb).                 |
| containerCondition | enumeration | serviceable, unusable, repairable, | Condition of container.                                       |
| lengthOS           | float       | numeric                            | Maximum external length of container in inches (in).          |
| widthOS            | float       | numeric                            | Maximum external width of container in inches (in).           |
| heightOS           | float       | numeric                            | Maximum external height of container in inches (in).          |
| weight             | float       | numeric                            | Maximum weight of empty container in pounds (lb).             |
| volumeOS           | float       | numeric                            | Maximum external volume of container in cubic feet (cf).      |
| volumeHolding      | float       | numeric                            | Maximum internal volume of container in cubic feet (cf).      |
| lengthHolding      | integer     | numeric                            | Maximum internal length of container in inches (in).          |
| widthHolding       | float       | numeric                            | Maximum internal width of container in inches (in).           |
| heightHolding      | float       | numeric                            | Maximum internal height of container in inches (in).          |
| stackingHeight     | integer     | numeric                            | Maximum number of containers that can be stacked.             |

## Appendix D: References

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## Appendix E: Acronyms

|         |   |
|---------|---|
| 2D      | Two-Dimensional   |
| 3D      | Three-Dimensional   |
| AALPS   | Automated Air Load Planning System  |
| AIT     | Automatic Identification Technology   |
| AOR     | Area of Responsibility  |
| API     | Application Programming Interface   |
| BEL     | Business Engine Layer   |
| BRL     | Business Rule Layer   |
| CAD     | Computer-Aided Design   |
| CADRC   | Collaborative Agent Design Research Center (California Polytechnic State University (Cal Poly), San Luis Obispo, California)              |
| CAM     | Computer-Aided Manufacturing  |
| CD-ROM  | Compact Disk – Read Only Memory   |
| CDM     | CDM Technologies, Inc., San Luis Obispo, California   |
| CFR     | Code of Federal Regulations (hazardous materials)   |
| CODES   | Computerized Deployment System  |
| CONUS   | Continental United States   |
| CPU     | Central Processing Unit (computer)  |
| DACMS   | Deployable Automatic Measuring System   |
| DCMNSN  | Dangerous Cargo Manifest National Stock Number (hazardous materials)  |
| DII-COE | Defense Information Infrastructure – Common Operating Environment   |
| DLL     | Dynamic Link Library  |
| DoD     | Department of Defense   |
| DoDIC   | Department of Defense Identification Code (hazardous materials)   |
| DOM     | Document Object Model   |
| DOS     | Disk Operating System   |
| E7      | military rank: Chief Petty Officer (Navy); Gunnery Sergeant (Marine Corps); Sergeant First Class (Army); and, Master Sergeant (Air Force) |
| E9      | military rank: Master Chief Petty Officer (Navy); Sergeant Major (Marine Corps and Army); and, Chief Master Sergeant (Air Force)          |
| ECF     | Equipment Characteristics File  |
| G2D     | Graphics 2D   |
| GATES   | Global Air Transportation Execution System  |

|        |   |
|--------|---|
| GB     | Giga Bytes (billion bytes)  |
| GHz    | Giga Hertz (billion cycles per second)                                  |
| GSG    | Generic Space Generator   |
| GUI    | Graphical User Interface  |
| GUIL   | Graphical User Interface Layer  |
| Hz     | Hertz (cycles per second)   |
| I-AIT  | ICODES - Automatic Identification Technology                            |
| IBS    | Integrated Booking System   |
| ICDM   | Integrated Cooperative Decision Making (software development framework) |
| ICODES | Integrated Computerized Deployment System                               |
| ID     | Identification  |
| IDAL   | Independent Data Access Layer   |
| IESI   | ICODES External Systems Interface                                       |
| IMDG   | International Maritime Dangerous Goods (hazardous materials)            |
| IMO    | International Maritime Organization                                     |
| IPIF   | ICODES Plug-In Framework  |
| ISF    | ICODES Stow Framework   |
| ISO    | International Standards Organization                                    |
| ITV    | In-Transit Visibility   |
| JCS    | Joint Chiefs of Staff   |
| JDBC   | Java Data-Base Connectivity   |
| JECF   | Joint Equipment Characteristics File                                    |
| JFCT   | Joint Forces Collaborative Toolkit                                      |
| JNI    | Java Native Interface   |
| JOGL   | Java bindings for OpenGL  |
| JSP    | JavaServer Pages  |
| KMES   | Knowledge Management Enterprise Services                                |
| L/T    | Long Ton (2,240 lb)   |
| LCG    | Longitudinal Center of Gravity  |
| LIN    | Line Item Number  |
| LOGAIS | Logistics Automated Information System                                  |
| LOLO   | Lift-On-Lift-Off  |
| M/T    | Measurement Ton (40 cubic feet)   |

|         |   |
|---------|---|
| MAGTF   | Marine Air and Ground Task Force  |
| MARAD   | Maritime Administration   |
| MDSS-II | MAGTF Deployment Support System   |
| MECF    | Marine Equipment Characteristics File   |
| MEU     | Marine Expeditionary Unit   |
| MTMC    | Military Traffic Management Command (renamed: Surface Distribution and Deployment Command)    |
| MVC     | Model-View-Controller   |
| NSN     | National Stock Number   |
| OAL     | Object Access Layer   |
| OML     | Object Management Layer   |
| OTL     | Object Transport Layer  |
| OpenGL  | Open Graphics Library   |
| PC      | Personal Computer   |
| PDA     | Personal Data Assistant   |
| PKG     | Package   |
| POD     | Port of Debarkation   |
| POE     | Port of Embarkation   |
| POW     | Promoting Object Wrapper  |
| RAM     | Random Access Memory  |
| RDBMS   | Relational Data-Base Management System  |
| REG     | Register  |
| RFID    | Radio Frequency Identification  |
| RORO    | Roll-On-Roll-Off  |
| SAX     | Simple API for XML  |
| RSA     | Rivest, Shamir, and Adelman (encryption technology)   |
| SDA     | Ship Data Access file   |
| SDDC    | Surface Deployment and Distribution Command (previously: Military Traffic Management Command) |
| SNID    | Semantic Network Identifier   |
| SOA     | Service-Oriented Architecture   |
| SQL     | Standard Query Language   |
| SVG     | Scalable Vector Graphics  |
| T-AVB   | class of ship (aviation logistics support ship)   |

|            |  |
|------------|--|
| TAMCN      | Table of Authorized Material Control Number                            |
| TALPS      | T-AVB Automated Load-Planning System                                   |
| TCP/IP     | Transmission Control Protocol / Internet Protocol                      |
| TCAIMS-II  | Transportation Coordinators' Automated Information for Movement System |
| TCG        | Transverse Center of Gravity   |
| TCN        | Transportation Control Number  |
| TDS        | Transaction Distribution System  |
| TL         | Translation Layer  |
| UDL        | Unit Deployment List   |
| UI         | User-Interface   |
| UIC        | Unit Identification Code   |
| UML        | Unified Modeling Language  |
| UN         | United Nations   |
| URI        | Uniform Resource Identifier  |
| URL        | Uniform Resource Locator   |
| US         | United States of America   |
| USMC       | United States Marine Corps   |
| USTRANSCOM | United States Transportation Command                                   |
| VCG        | Vertical Center of Gravity   |
| WIM        | Weigh In Motion  |
| WPS        | World-Wide Port System   |
| XML        | Extensible Markup Language   |